

# SSME ALTERNATE TURBOPUMP DEVELOPMENT PROGRAM (HPFTP)

## VERIFICATION COMPLETE REPORT SECOND TURBINE VANE AERODYNAMIC DESIGN DVS DR NO. 3.1.2.2.4.1, VM NO. 4.1.2.4 A

JUNE 1989

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Prepared for  
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National Aeronautics and Space Administration  
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(NASA-CR-183752) SSME ALTERNATE TURBOPUMP  
DEVELOPMENT PROGRAM (HPFTP). VERIFICATION  
COMPLETE REPORT. SECOND TURBINE VANE  
AERODYNAMIC DESIGN DVS DR NO. 3.1.2.2.4.1,  
VM NO. 4.1.2.4 A (Pratt and Whitney

N89-71481

00/20      Unclassified  
              0233360



**UNITED  
TECHNOLOGIES  
PRATT & WHITNEY**

### HPFTP Turbine Aerodynamic Design

The High Pressure Fuel Turbopump (HPFTP) turbine aerodynamic design is based on the requirements defined by the Interface Control Document (ICD) and by the Power Balance Model, Table 387B. Performance Table 387B was used for the turbine aerodynamic design because its turbine flow capacities are consistent with the baseline turbine nozzle flow test results conducted on Pratt & Whitney's test stand, E-6, in December, 1986.

A conventional pressure-compounded, 2-stage turbine was chosen because of its inherent high efficiency over a wide range of steady-state operating conditions. No exit guide vane is required for the small (18 degrees) exit swirl angle. The high airfoil gas bending loads in the HPFTP turbine required thin wall, hollow airfoil sections, with larger moments of inertia, in order to reduce the airfoil bending stresses. The HPFTP turbine design has a mean diameter wheel speed of 1482 ft/sec which is compatible with allowable disk and root attachment stress criteria. This wheel speed also provides a high design point wheel speed to gas velocity ratio, assuring that there will not be a significant efficiency loss at minimum power level (MPL) operation. The design point velocity ratio, (0.55) is conservative, ensuring minimal aerodynamic risk. The design speed of approximately 36,500 rpm selected for the HPFTP was primarily set by the pump hydrodynamics. The height of the turbine annulus was selected to limit the last stage blade root centrifugal stress to 46,000 psi. This annulus size yielded a favorable exit Mach number of 0.18 and a low exit swirl angle of 18 degrees, therefore, this rpm was satisfactory to the performance, stress, and exit Mach number requirements of the turbine.

The methodology associated with the design of the HPFTP starts with the meanline design analysis. This analysis is based on the assumption that the flow through the turbine can be represented by the flow at the center of the flow passage. This simplified approach permits selection of the number of stages required, the mean diameter of the flow passage, and the annulus area. Included in the analysis is an estimate of the aerodynamic efficiency. This prediction system uses the physical laws of aerodynamics and correlations from rig and engine data to estimate profile loss, secondary loss, blade tip leakage, and shock and incidence losses based on the geometry and aerodynamic parameters of the turbine. An interactive graphic flowpath design system is used, in conjunction with the optimum meanline design, to generate candidate flowpath configurations.

The streamline design analysis is used to optimize the radial variation in the velocity triangles, once the average conditions are selected from the meanline analysis. This analysis calculates the flow characteristics at numerous radial locations and at the inlet and exit of each airfoil row. Once the meanline and streamline analyses have been used to optimize the velocity triangles throughout the turbine, 2 dimensional (2-D) airfoil sections are designed. These airfoil sections are designed to achieve contours that provide the desired amount of flow turning without permitting the flow to separate from

the airfoil surface. This process involves determining the static pressure distributions and boundary layer parameters along the airfoil surfaces and endwalls. An interactive graphics airfoil design system is used to identify adverse static pressure gradients such that the airfoil contour can be modified appropriately. After the 2-D airfoils are estimated at several spanwise locations, they are radially faired and combined with a preliminary endwall definition. An inviscid multi-stage 3-D flow analysis is then used to refine and optimize the entire flowpath configuration.

All turbine airfoil, endwall, inlet, and exit flow passage surfaces are contoured and refined as a system. The multi-stage feature enables a complete evaluation of potential changes to an individual surface contour during the design process. This assessment includes, not only flow property changes around the component being modified, but also around all upstream and downstream components in the complete turbine system. Improved performance and reduced risk result from this global optimization capability.

This report contains:

- o Hot elevation diagrams for each airfoil
- o 3-D airfoil plots
- o 2-D airfoil section plots
- o Tabulated airfoil section coordinates
- o A plot of hot gaging dimensions versus radius
- o A plot of percent change in flow area versus airfoil rotation
- o A plot of stress versus span
- o 3-D airfoil static pressure distributions
- o Airfoil Ps/PT and Mach number contours
- o A plot of suction surface boundary layer friction coefficient versus surface distance

COVER SHEET

S.S.M.E.  
ENGINE Alternate Turbo-Pump Development

AIRFOIL 2nd Stage Vane

ENGINEER R.J. Rowey EXT 5962 DATE 8/24/87

AERODYNAMIC DESIGN POINT 109% Power - Design Table 0387.8 dated 4/10/87

F.T.D. LIST:

ELEVATION \_\_\_\_\_

AIRFOIL SECTIONS \_\_\_\_\_

AIRFOIL COORDINATES \_\_\_\_\_

DF LIST:

GAGING VS. RADIUS \_\_\_\_\_

FLOW AREA VS. ROTATION \_\_\_\_\_

STRESS VS. % SPAN \_\_\_\_\_

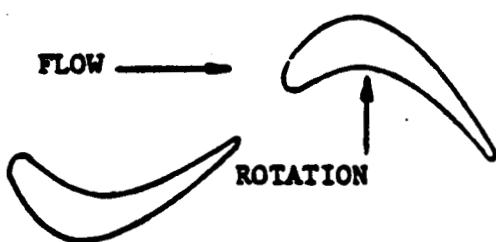
PRESSURE DIST. \_\_\_\_\_

BOUNDARY LAYER \_\_\_\_\_

CHECK ONE

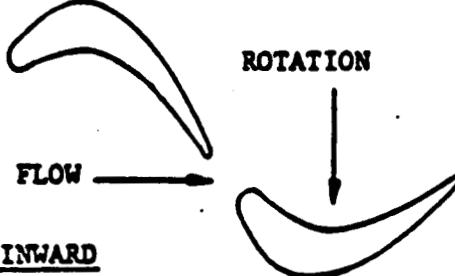
P&WA CONVENTIONAL ROTATION

VANE \_\_\_\_\_ BLADE

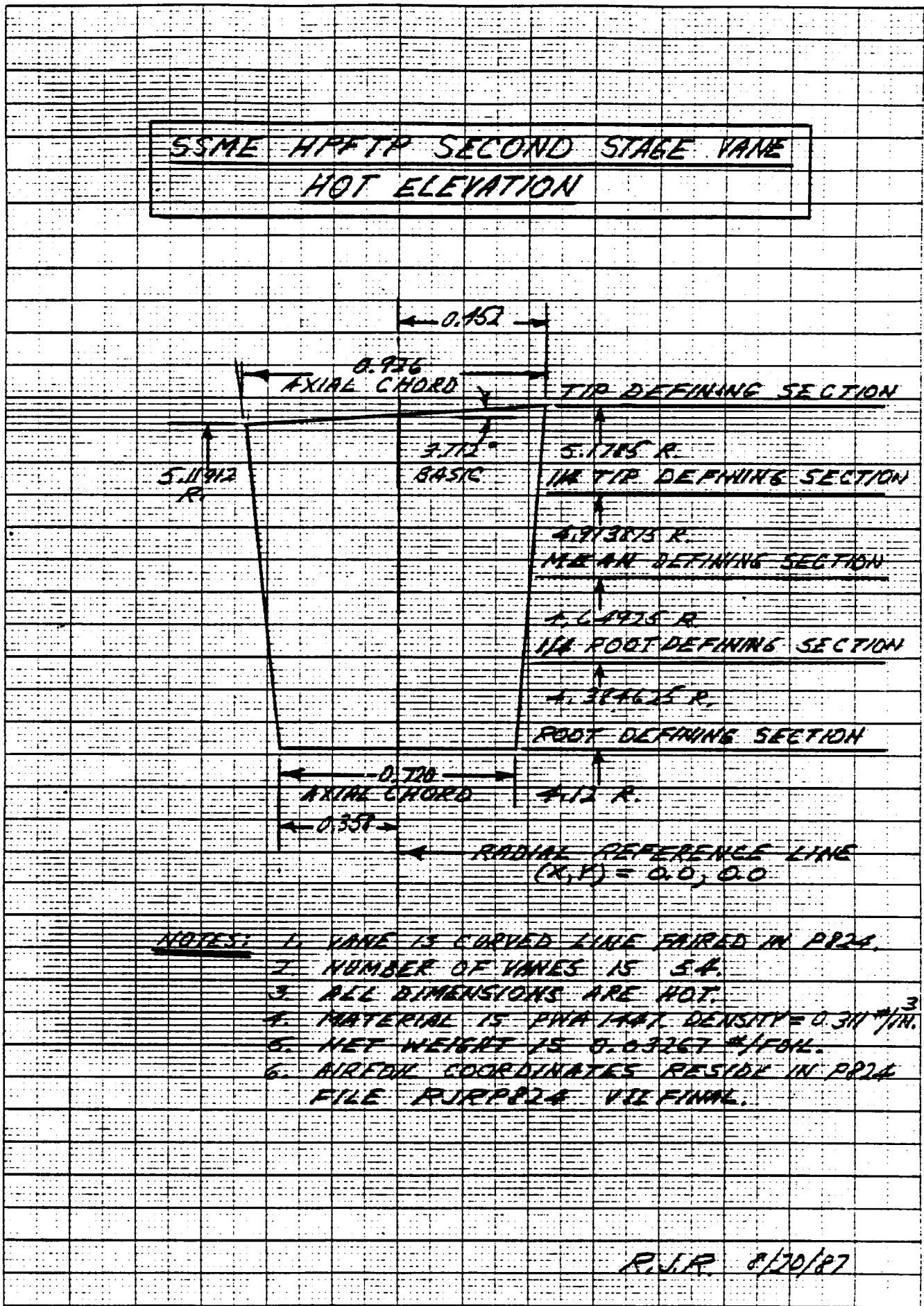


P&WA COUNTER ROTATION

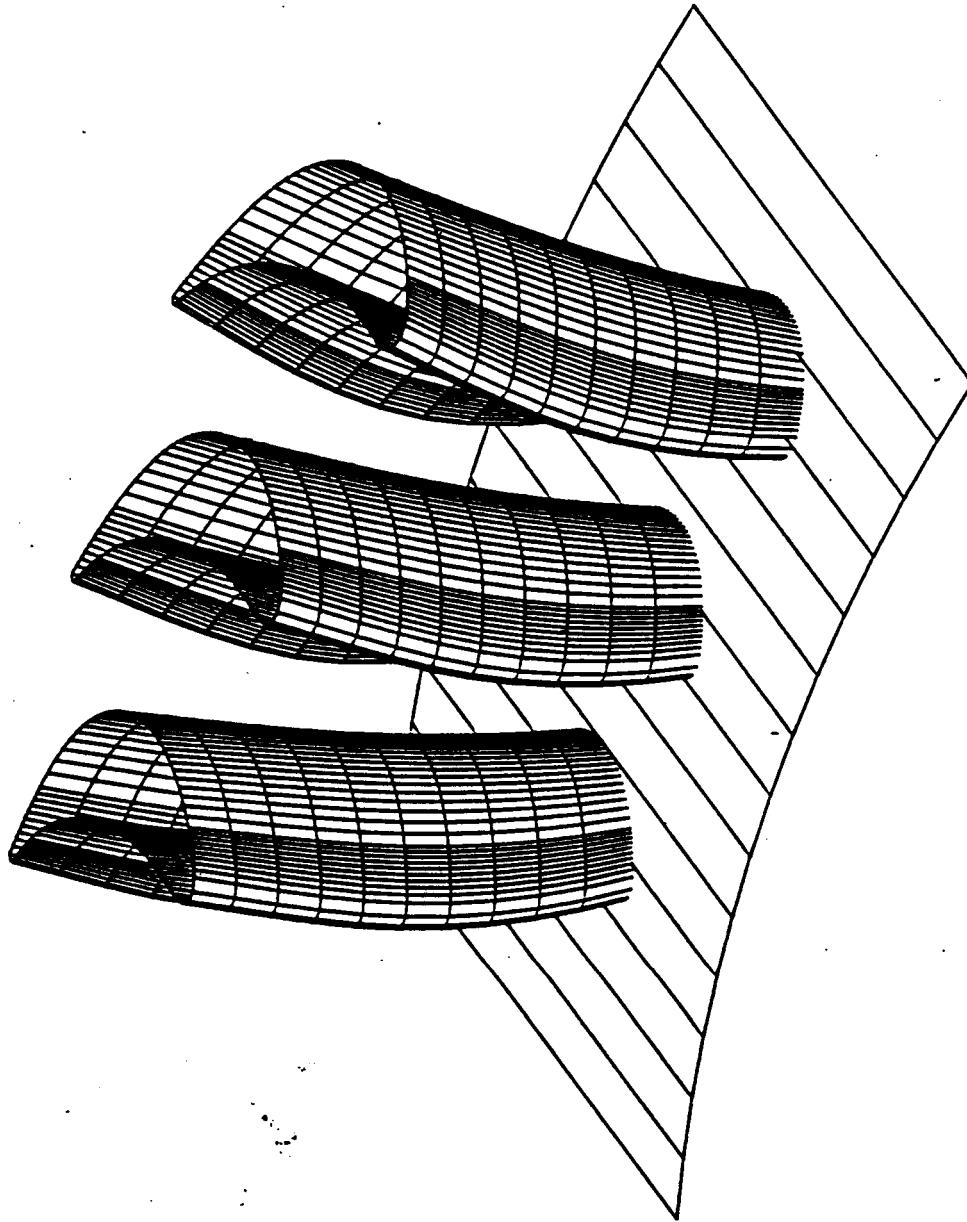
VANE \_\_\_\_\_ BLADE \_\_\_\_\_



VIEW LOOKING RADIALLY INWARD



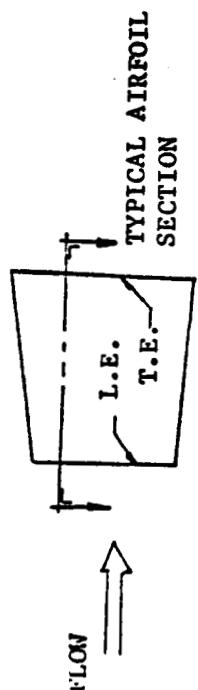
3D PLOT



SSME FT FINAL 2V...R.J.ROWEY...5-13-87.. . 39.36 54.47 36.05  
05/26/87 15:36:35

SSME FT FINAL 2V. R. J. ROWLEY. 6-9-87  
ROOT

CYLINDRICAL	
SCALE 5.0	
THERMAL SHRINK FACTOR	1.00000
08/19/87	
11.46.59	
NUMBER OF VANES	54.
RADIUS (MOT)	4.120 INCHES
CAGING (MOT)	0.2154 INCHES
PITCH (MOT)	0.4794 INCHES
AxIAL WIDTH	0.7220 INCHES
VANE INLET ANGLE	60.351 DEGREES
CAS INLET ANGLE	45.780 DEGREES
VANE EXIT ANGLE	27.189 DEGREES
CAS EXIT ANGLE	27.224 DEGREES
CAGING ANGLE	26.699 DEGREES
UNCOVERED TURNING	19.874 DEGREES
LEADING EDGE RADIUS	0.0131 INCHES
TRAILING EDGE RADIUS	0.0125 INCHES
TOTAL AREA (SOLID)	0.1174 SQ. IN.
METAL AREA	0.0849 SQ. IN.
'NET. UNCOATED)	

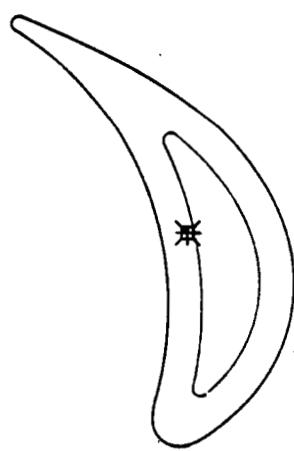


ENGINE

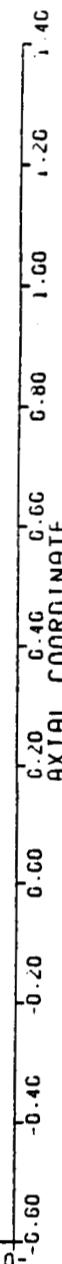
CLOCKWISE ROTATION WHEN LOOKING FORWARD

NOMINAL ENGINE POSITION

X C.C.	-0.0000	C.0001
+ STACKING LINE	0.0000	0.0000
CAGE	0.1815	-0.0455

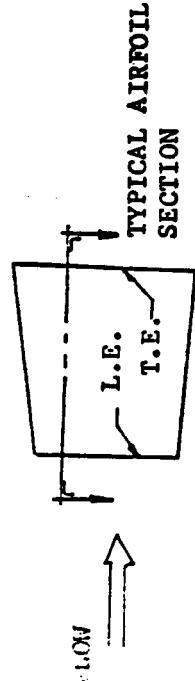


TANGENTIAL COORDINATE 0.40 0.20 0.00 0.20 0.40 0.60 0.80 1.00 1.20 1.40



SSME FT FINAL 2V. R. J. ROWLEY 6-9-87

1/4 ROOT

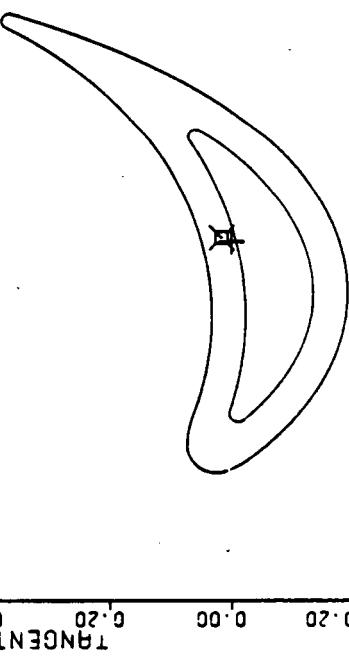


CLOCKWISE ROTATION WHEN LOOKING FORWARD

NOMINAL ENGINE POSITION

CYLINDRICAL  
SCALE 5.0  
THERMAL SHRINK FACTOR 1.00000  
CB/19/87  
11.46.59

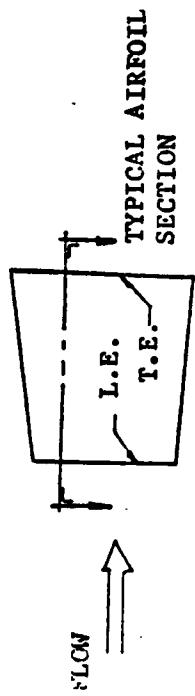
NUMBER OF VANES 54.  
RADIUS (HGT), 4.385 INCHES  
CAGING (HGT), 0.1950 INCHES  
PITCH (HGT), 0.5102 INCHES  
ACTAL WIDTH 0.7715 INCHES  
VANE INLET ANGLE 58.324 DEGREES  
CAS INLET ANGLE 42.000 DEGREES  
VANE EXIT ANGLE 21.681 DEGREES  
CAS EXIT ANGLE 21.681 DEGREES  
CAGING ANGLE 22.477 DEGREES  
UNCOVERED TURNING 20.314 DEGREES  
LEADING EDGE RADIUS 0.0459 INCHES  
TRAILING EDGE RADIUS 0.0124 INCHES  
TOTAL AREA (SOLO) 0.1387 SQ. IN.  
METAL AREA 0.0937 SQ. IN.  
(NET, UNCOATED)



X C.C. 0.0067 0.0159  
+ STACKING LINE 0.0000 0.0000  
CRGE 0.2075 0.0209

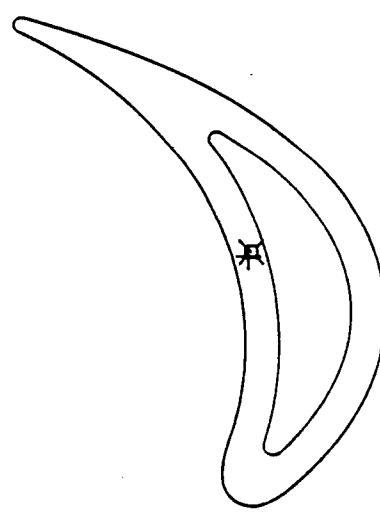
SSME FT FINAL 2V.. R.J. ROWER G-9-87

MEAN



CLOCKWISE ROTATION WHEN LOOKING FORWARD

NOMINAL ENGINE POSITION



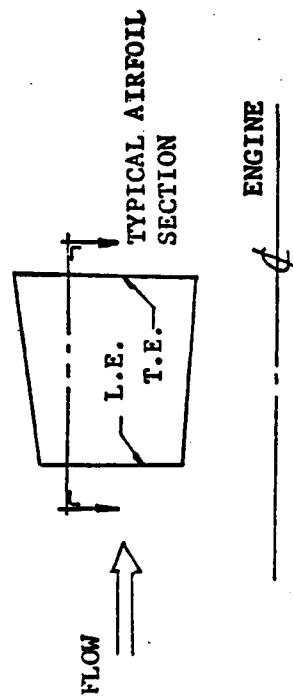
CYLINDRICAL	
SCALE	5.0
THERMAL SHRINK FACTOR	1.00000
CG/9/87	
11.46:59	
NUMBER OF VANEES	54.
RADIUS (HOT)	4.649 INCHES
ENGINE (HOT)	0.2032 INCHES
SPACER (HOT)	0.5410 INCHES
AXIAL WIDTH	0.8280 INCHES
VANE INLET ANGLE	60.816 DEGREES
GAS INLET ANGLE	43.250 DEGREES
VANE EXIT ANGLE	21.056 DEGREES
GAS EXIT ANGLE	21.037 DEGREES
CAGING ANGLE	22.064 DEGREES
UNCOVERED TURNING	20.456 DEGREES
LEADING EDGE RADIUS	0.0480 INCHES
TRAILING EDGE RADIUS	0.0125 INCHES
TOTAL AREA (SOLID)	0.1553 SC. IN.
METAL AREA (NET, UNCOATED)	0.1047 SC. IN.

X	Y
X C.G.	0.000
+ STACKING LINE	0.0000
CAGE	0.2221 -0.0404



SSME FT FINAL 2V R. J. POWER 6-9-87.

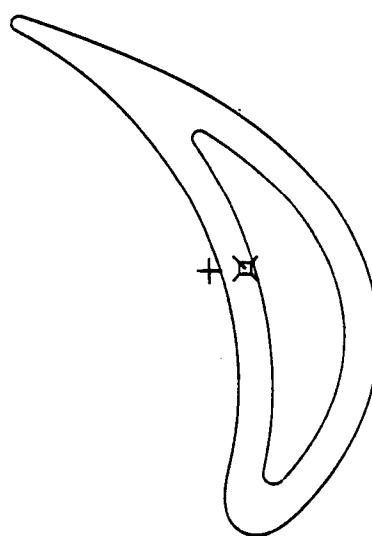
1/4 TIP



CLOCKWISE ROTATION WHEN LOOKING FORWARD

#### NOMINAL ENGINE POSITION

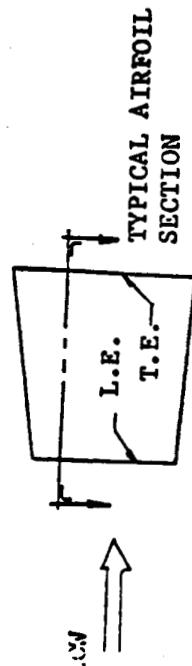
NUMBER OF VANES	54.
RADIUS (HOT)	4.914 INCHES
GAGING (HOT)	0.2355 INCHES
PITCH (HOT)	0.5718 INCHES
AXIAL WIDTH	0.8745 INCHES
VANE INLET ANGLE	67.0086 DEGREES
CAS INLET ANGLE	48.310 DEGREES
VANE EXIT ANGLE	23.234 DEGREES
CAS EXIT ANGLE	23.234 DEGREES
GAGING ANGLE	24.328 DEGREES
UNCOVERED TURNING	
LEADING EDGE RADIUS	0.0488 INCHES
TRAILING EDGE RADIUS	0.0126 INCHES
TOTAL AREA (SOLID)	0.1665 SQ. IN.
METAL. AREA	0.1090 SQ. IN.
(NET, UNCOATED)	



X C.G.	0.0043	X	0.0043	X	-0.0597
+ STACKING LINE	0.0000	+	0.0000	+	0.0000
CGAE	0.2260		-0.1021		

SSME FT FINAL 2V.. R.J. ROWLEY. 6-9-87.

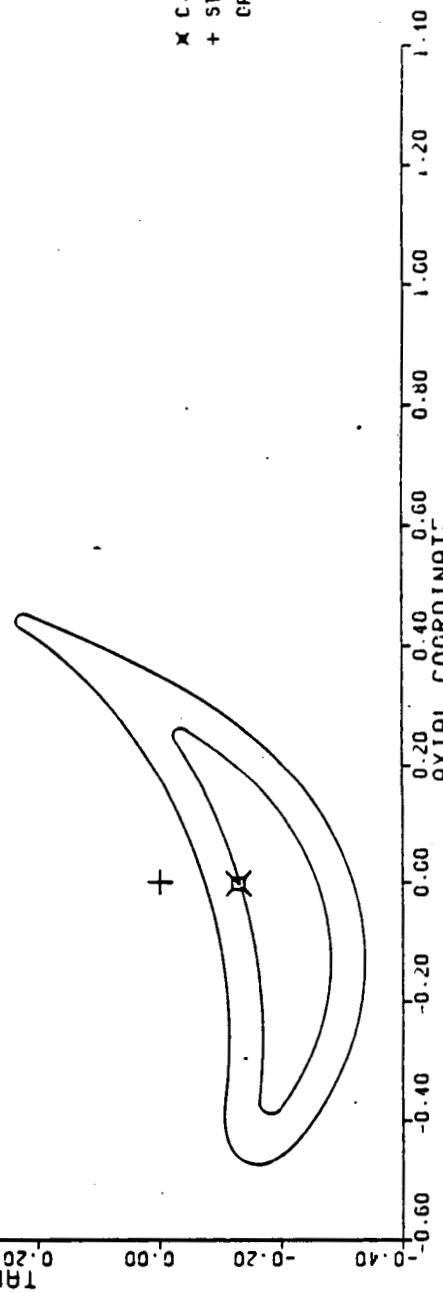
TIP



CLOCKWISE ROTATION WHEN LOOKING FORWARD

NOMINAL ENGINE POSITION

CYLINDRICAL  
SCALE 5.0  
THERMAL SHRINK FACTOR 1.00000  
08/19/87  
11:46:59  
NUMBER OF VANES 54.  
RADIUS (HOT) 5.178 INCHES  
CAGING (HOT) 0.2808 INCHES  
PITCH (HOT) 0.6025 INCHES  
AXIAL WIDTH 0.9260 INCHES  
VANE INLET ANGLE 74.022 DEGREES  
CAS INLET ANGLE 62.000 DEGREES  
VANE EXIT ANGLE 27.243 DEGREES  
CAS EXIT ANGLE 27.224 DEGREES  
CAGING ANGLE 27.776 DEGREES  
UNCOVERED TURNING 20.961 DEGREES  
LEADING EDGE RADIUS 0.0481 INCHES  
TRAILING EDGE RADIUS 0.0125 INCHES  
TOTAL AREA (SOLID) 0.1752 SQ. IN.  
METAL AREA 0.1115 SQ. IN.  
NET. UNCOATED)



EXTERNAL C JNR. TITLE - SSME FT FINAL 2V...R.J. ROMEY...6  
 TD 0 REV. 0 PART NO. END NO. DA.- 08/19/87 TIME 11:46:42  
 SUBTITLE ROOT HOT RADIUS = 4.12000 COLD RADIUS = 4.11200 THERMAL SHRINK FACTOR = 1.00000

PRENTIST NOT USED FOR TD PRINTOUT.

PCT X	X TOP	Y TOP	(CIRCLE)	X BOT	Y BOT	(CIRCLE)
0.0	-0.35802	0.00422	0.01239	-0.35802	0.00467	0.01289
0.010	-0.35082	-0.01224		-0.35082	0.00461	0.01276
0.020	-0.34362	-0.02589		-0.34362	0.04733	0.04507
0.030	-0.33642	-0.03674		-0.33642	0.05162	0.05027
0.040	-0.32922	-0.04656		-0.32922	0.05396	0.05258
0.050	-0.32202	-0.05573		-0.32202	0.05546	0.05544
0.060	-0.31482	-0.06436		-0.31482	0.05618	
0.070	-0.30762	-0.07245		-0.30762	0.05626	
0.080	-0.30042	-0.08015		-0.30042	0.05582	
0.090	-0.29322	-0.08734		-0.29322	0.05491	
0.100	-0.28602	-0.09414		-0.28602	0.05359	
0.125	-0.26802	-0.10953		-0.26802	0.04909	
0.150	-0.25002	-0.12283		-0.25002	0.04487	
0.175	-0.23202	-0.13428		-0.23202	0.04123	
0.200	-0.21402	-0.14408		-0.21402	0.03815	
0.225	-0.19602	-0.15235		-0.19602	0.03563	
0.250	-0.17802	-0.15920		-0.17802	0.03348	
0.275	-0.16002	-0.16472		-0.16002	0.03228	
0.300	-0.14202	-0.16899		-0.14202	0.03145	
0.325	-0.12402	-0.17204		-0.12402	0.03117	
0.350	-0.10602	-0.17335		-0.10602	0.03165	
0.375	-0.08802	-0.17469		-0.08802	0.03230	
0.400	-0.07002	-0.17434		-0.07002	0.03373	
0.425	-0.05202	-0.17289		-0.05202	0.03573	
0.450	-0.03402	-0.17034		-0.03402	0.03833	
0.475	-0.01602	-0.16671		-0.01602	0.04154	
0.500	0.00198	-0.16198		0.00198	0.04536	
0.525	0.01998	-0.15613		0.01998	0.04981	
0.550	0.03798	-0.14216		0.03798	0.05423	
0.575	0.05598	-0.14097		0.05598	0.06072	
0.600	0.07398	-0.13159		0.07398	0.06722	
0.625	0.09198	-0.12091		0.09198	0.07445	
0.650	0.10998	-0.10982		0.10998	0.08245	
0.675	0.12798	-0.09533		0.12798	0.09126	
0.700	0.14598	-0.08040		0.14598	0.10094	
0.725	0.16398	-0.06364		0.16398	0.11153	
0.750	0.18198	-0.04501		0.18198	0.12311	
0.775	0.19998	-0.02420		0.19998	0.13576	
0.800	0.21798	-0.00498		0.21798	0.14957	
0.825	0.23598	0.02490		0.23598	0.16467	
0.850	0.25398	0.05353		0.25398	0.18120	
0.875	0.27198	0.08494		0.27198	0.19936	
0.900	0.28998	0.11902		0.28998	0.21940	
0.950	0.32598	0.19434		0.32598	0.26658	
0.960	0.33318	0.21039		0.33318	0.27745	
0.970	0.34038	0.22674		0.34038	0.28892	
0.980	0.34758	0.24378		0.34758	0.30105	
0.990	0.35478	0.26023		0.35478	0.31395	
1.000	0.36198	0.27734	0.27985	0.36198	0.32771	0.27985

NO. 1 CORE VTOUR  
TD 0 REV. 0 PART NO.  
S:BTITLE R017

TITLE - SSM FT FINAL 2V...R.J. ROMEY...6  
END NO.  
HOT RADIUS = 4.12000  
COLD RADIUS = 4.11200  
THERMAL SHRINK FACTOR = 1.00000

7...  
DA.. 08/19/87 TIME 11:46:42  
CYLINDRICAL

PARTS NOT USED FOR TD PRINTOUT.

PCT X	X TOP	Y TOP	(CIRCLE)	X BOT	Y BOT	(CIRCLE)
0.0	-0.27322	-0.02264	-0.02261	-0.27322	-0.00682	-0.02261
0.010	-0.26881	-0.03212	-0.03211	-0.26881	-0.01785	-0.01291
0.020	-0.26441	-0.03700	-0.03700	-0.26441	-0.00886	-0.01050
0.030	-0.26000	-0.04170	-0.04170	-0.26000	-0.00983	-0.00993
0.040	-0.25559	-0.04622	-0.04622	-0.25559	-0.01078	
0.050	-0.25118	-0.05054	-0.05054	-0.25118	-0.01170	
0.060	-0.24678	-0.05468	-0.05468	-0.24678	-0.01258	
0.070	-0.24237	-0.05863	-0.05863	-0.24237	-0.01343	
0.080	-0.23796	-0.06240	-0.06240	-0.23796	-0.01424	
0.090	-0.23356	-0.06600	-0.06600	-0.23356	-0.01502	
0.100	-0.22915	-0.06943	-0.06943	-0.22915	-0.01576	
0.125	-0.21813	-0.07735	-0.07735	-0.21813	-0.01748	
0.150	-0.20712	-0.08440	-0.08440	-0.20712	-0.01901	
0.175	-0.19610	-0.09071	-0.09071	-0.19610	-0.02035	
0.200	-0.18508	-0.09631	-0.09631	-0.18508	-0.02150	
0.225	-0.17406	-0.10125	-0.10125	-0.17406	-0.02246	
0.250	-0.16305	-0.10553	-0.10553	-0.16305	-0.02346	
0.275	-0.15203	-0.10916	-0.10916	-0.15203	-0.02582	
0.300	-0.14101	-0.11223	-0.11223	-0.14101	-0.02640	
0.325	-0.12999	-0.11469	-0.11469	-0.12999	-0.02640	
0.350	-0.11898	-0.11660	-0.11660	-0.11898	-0.02440	
0.375	-0.10796	-0.11797	-0.11797	-0.10796	-0.02440	
0.400	-0.09694	-0.11881	-0.11881	-0.09694	-0.02382	
0.425	-0.08592	-0.11913	-0.11913	-0.08592	-0.02325	
0.450	-0.07421	-0.11823	-0.11823	-0.07421	-0.02243	
0.475	-0.06389	-0.11822	-0.11822	-0.06389	-0.02151	
0.500	-0.05267	-0.11701	-0.11701	-0.05267	-0.02035	
0.525	-0.04185	-0.11529	-0.11529	-0.04185	-0.01899	
0.550	-0.03084	-0.11308	-0.11308	-0.03084	-0.01742	
0.575	-0.01982	-0.11035	-0.11035	-0.01982	-0.01564	
0.600	-0.00880	-0.10717	-0.10717	-0.00880	-0.01366	
0.625	0.00222	-0.10346	-0.10346	0.00222	-0.01147	
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0.675	0.02425	-0.09449	-0.09449	0.02425	-0.00646	
0.700	0.03527	-0.08921	-0.08921	0.03527	-0.00362	
0.725	0.04629	-0.08339	-0.08339	0.04629	-0.00056	
0.750	0.05730	-0.07701	-0.07701	0.05730	0.00272	
0.775	0.06832	-0.07005	-0.07005	0.06832	0.00624	
0.800	0.07934	-0.06249	-0.06249	0.07934	0.01000	
0.825	0.09036	-0.05429	-0.05429	0.09036	0.01400	
0.850	0.10137	-0.04545	-0.04545	0.10137	0.01825	
0.875	0.11239	-0.03592	-0.03592	0.11239	0.02275	
0.900	0.12341	-0.02563	-0.02563	0.12341	0.02751	
0.920	0.13222	-0.01682	-0.01682	0.13222	0.03150	
0.930	0.13663	-0.01221	-0.01221	0.13663	0.03357	
0.940	0.14104	-0.00744	-0.00744	0.14104	0.03568	
0.950	0.14544	-0.00252	-0.00252	0.14544	0.03784	
0.960	0.14985	0.00254	0.00254	0.14985	0.04003	
0.970	0.15426	0.00776	0.00776	0.15426	0.04110	
0.980	0.15867	0.01513	0.01513	0.15867	0.04057	
0.990	0.16307	0.01866	0.01866	0.16307	0.03815	
1.000	0.16748	0.02436	0.02436	0.16748	0.02862	

EXTERNAL 1 CUR 0 .J REV. 0 PART NO.  
TD 0 END NO. SUBTITLE 1/4 ROOT

TITLE - SSME FT FINAL 2V...R.J. ROMEY...6 17..  
END NO. DATE 08/19/87 TIME 11:46:42 CYLINDRICAL  
COLD RADIUS = 4.37400 THERMAL SHRINK FACTOR = 1.000000

PRETMIST NOT USED FOR TD PRINTOUT.

PCT X	X TOP	Y TOP	(CIRCLE)	X BOT	Y BOT	(CIRCLE)
0.0	-0.38702	0.01771	0.02676	-0.38702	0.04635	0.02676
0.010	-0.37930	-0.00029		-0.37930	0.05471	0.05224
0.020	-0.37159	-0.01523		-0.37159	0.06401	0.06110
0.030	-0.36387	-0.02711		-0.36387	0.06824	0.06664
0.040	-0.35616	-0.03748		-0.35616	0.07078	0.07015
0.050	-0.34844	-0.04707		-0.34844	0.07220	0.07210
0.060	-0.34073	-0.05629		-0.34073	0.07275	
0.070	-0.33301	-0.06511		-0.33301	0.07261	
0.080	-0.32530	-0.07353		-0.32530	0.07190	
0.090	-0.31759	-0.08156		-0.31759	0.07068	
0.100	-0.30987	-0.08922		-0.30987	0.06901	
0.125	-0.2958	-0.10686		-0.2958	0.06316	
0.150	-0.27130	-0.12247		-0.27130	0.05644	
0.175	-0.25201	-0.13621		-0.25201	0.05053	
0.200	-0.23272	-0.14822		-0.23272	0.04547	
0.225	-0.21343	-0.15858		-0.21343	0.04124	
0.250	-0.19415	-0.16737		-0.19415	0.03783	
0.275	-0.17486	-0.17465		-0.17486	0.03523	
0.300	-0.15557	-0.18048		-0.15557	0.03244	
0.325	-0.13620	-0.18488		-0.13620	0.03023	
0.350	-0.11700	-0.18720		-0.11700	0.02823	
0.375	-0.09771	-0.18955		-0.09771	0.0284	
0.400	-0.07842	-0.18986		-0.07842	0.03424	
0.425	-0.05913	-0.18892		-0.05913	0.03647	
0.450	-0.03285	-0.18642		-0.03285	0.03952	
0.475	-0.02056	-0.18267		-0.02056	0.04340	
0.500	-0.00127	-0.17755		-0.00127	0.04814	
0.725	0.01802	-0.17105		0.01802	0.05375	
0.550	0.03710	-0.16311		0.03710	0.06025	
0.575	0.05659	-0.15372		0.05659	0.06769	
0.600	0.07588	-0.14280		0.07588	0.07608	
0.625	0.09517	-0.13031		0.09517	0.08547	
0.650	0.11445	-0.11616		0.11445	0.09590	
0.675	0.13374	-0.10027		0.13374	0.10743	
0.700	0.15303	-0.09251		0.15303	0.12012	
0.725	0.17232	-0.06274		0.17232	0.13404	
0.750	0.19160	-0.04079		0.19160	0.14929	
0.775	0.21089	-0.01644		0.21089	0.16598	
0.800	0.23010	0.01058		0.23010	0.18422	
0.825	0.24947	0.04057		0.24947	0.20419	
0.850	0.26875	0.07385		0.26875	0.22607	
0.875	0.28804	0.11073		0.28804	0.25014	
0.900	0.30733	0.15150		0.30733	0.27673	
0.950	0.34590	0.24649		0.34590	0.33945	
0.960	0.35362	0.26777		0.35362	0.35393	
0.970	0.36133	0.28987		0.36133	0.36916	
0.980	0.36905	0.31279		0.36905	0.37505	
0.990	0.37676	0.33656		0.37676	0.37452	
1.000	0.38448	0.36119	0.36306	0.38448	0.42100	0.36306

ND. 1 CORE ITOUR  
TD 0 .W REV. 0 PART NO.  
SUBTITLE 1/4 ROOT

TITLE - SSMF FT FINAL 2V...R.J. ROMEY..6  
DATE 08/19/87 TIME 11:46:42  
EMD NO. COLD RADIUS = 4.36463  
HOT RADIUS = 4.37400 THERMAL SHRINK FACTOR = 1.00000

PENTIST NOT USED FOR TD PRINTOUT.

PCT X	X TOP	Y TOP	(CIRCLE)	X BOT	Y BOT	(CIRCLE)
0.0	-0.30197	-0.01643	-0.01038	-0.30197	0.00083	-0.01038
0.010	-0.29705	-0.02131		-0.29705	0.00717	0.00024
0.020	-0.29212	-0.02701		-0.29212	0.00555	0.00293
0.030	-0.28719	-0.03254		-0.28719	0.00396	0.00352
0.040	-0.28226	-0.03783		-0.28226	0.00240	
0.050	-0.27734	-0.04305		-0.27734	0.00088	
0.060	-0.27241	-0.04833		-0.27241	-0.00661	
0.070	-0.26748	-0.05283		-0.26748	-0.00207	
0.080	-0.26256	-0.05745		-0.26256	-0.01647	
0.090	-0.25763	-0.06190		-0.25763	-0.00484	
0.100	-0.25270	-0.06619		-0.25270	-0.00616	
0.125	-0.24038	-0.07622		-0.24038	-0.00927	
0.150	-0.22807	-0.08533		-0.22807	-0.01208	
0.175	-0.21575	-0.09360		-0.21575	-0.01457	
0.200	-0.20343	-0.10105		-0.20343	-0.01672	
0.225	-0.19111	-0.10773		-0.19111	-0.01857	
0.250	-0.17879	-0.11363		-0.17879	-0.02012	
0.275	-0.16648	-0.11875		-0.16648	-0.02138	
0.300	-0.15416	-0.12313		-0.15416	-0.02232	
0.325	-0.14184	-0.12673		-0.14184	-0.02298	
0.350	-0.12952	-0.12971		-0.12952	-0.02334	
0.375	-0.11720	-0.13194		-0.11720	-0.02340	
0.400	-0.10489	-0.13347		-0.10489	-0.02316	
0.425	-0.09257	-0.13429		-0.09257	-0.02262	
0.450	-0.08025	-0.13442		-0.08025	-0.02177	
0.475	-0.06793	-0.13385		-0.06793	-0.02063	
0.500	-0.05562	-0.13260		-0.05562	-0.01919	
0.525	-0.04330	-0.13064		-0.04330	-0.01744	
0.550	-0.03028	-0.12801		-0.03028	-0.01538	
0.575	-0.01866	-0.12467		-0.01866	-0.01300	
0.600	-0.00634	-0.12064		-0.00634	-0.01032	
0.625	0.00597	-0.11589		0.00597	-0.00730	
0.650	0.01829	-0.11043		0.01829	-0.00597	
0.675	0.03061	-0.10426		0.03061	-0.00331	
0.700	0.04293	-0.09732		0.04293	0.00369	
0.725	0.05525	-0.08965		0.05525	0.00802	
0.750	0.06756	-0.08119		0.06756	0.01271	
0.775	0.07988	-0.07194		0.07988	0.01775	
0.800	0.09220	-0.06187		0.09220	0.02314	
0.825	0.10452	-0.05095		0.10452	0.02892	
0.850	0.11684	-0.03916		0.11684	0.03508	
0.875	0.12915	-0.02642		0.12915	0.04163	
0.900	0.14147	-0.01275		0.14147	0.04859	
0.910	0.14640	-0.00700		0.14640	0.05147	
0.920	0.15133	-0.00109		0.15133	0.05443	
0.930	0.15625	0.00500		0.15625	0.05746	
0.940	0.16118	0.01123		0.16118	0.06056	
0.950	0.16611	0.01774		0.16611	0.06372	
0.960	0.17103	0.02439		0.17103	0.06695	
0.970	0.17596	0.03124		0.17596	0.07026	0.06905
0.980	0.18089	0.03831		0.18089	0.07363	0.06899
0.990	0.18582	0.04560		0.18582	0.07709	0.06673
1.000	0.19074	0.05312	0.05681	0.19074	0.08062	0.05681

EXTERNAL C X/R  
TL 0 .-. REV. 0 PART NO.  
SUBTITLE MEAN

TITLE - SSME FT FINAL 2V...R.J. ROMEY...6  
END NO.  
HOT RADIUS = 4.64925

CYLINDRICAL  
THERMAL SHRINK FACTOR = 1.00000

PRETEST NOT USED FOR TO PRINTOUT.

PCT	X	X TOP	Y TOP	(CIRCLE)	X BOT	Y BOT	(CIRCLE)
0.0	-0.41602	-0.01327	-0.00368	-0.41602	0.01639	-0.00368	
0.010	-0.40779	-0.03177		-0.40779	0.02750	0.02540	
0.020	-0.39956	-0.04704		-0.39956	0.03503	0.03270	
0.030	-0.39133	-0.05922		-0.39133	0.03959	0.03848	
0.040	-0.38310	-0.06962		-0.38310	0.04239	0.04209	
0.050	-0.37487	-0.07910		-0.37487	0.04403	0.04403	
0.060	-0.36664	-0.08819		-0.36664	0.04477		
0.070	-0.35841	-0.09692		-0.35841	0.04481		
0.080	-0.35018	-0.10525		-0.35018	0.04424		
0.090	-0.34195	-0.11330		-0.34195	0.04316		
0.100	-0.33372	-0.12099		-0.33372	0.04160		
0.125	-0.31315	-0.13877		-0.31315	0.03588		
0.150	-0.29257	-0.15465		-0.29257	0.02897		
0.175	-0.27200	-0.16872		-0.27200	0.02295		
0.200	-0.25142	-0.18108		-0.25142	0.01786		
0.225	-0.23085	-0.19180		-0.23085	0.01367		
0.250	-0.21027	-0.20093		-0.21027	0.01036		
0.275	-0.18970	-0.20854		-0.18970	0.00793		
0.300	-0.16912	-0.21466		-0.16912	0.00637		
0.325	-0.14855	-0.21930		-0.14855	0.00567		
0.350	-0.12797	-0.22251		-0.12797	0.00582		
0.375	-0.10740	-0.22429		-0.10740	0.00684		
0.400	-0.08682	-0.22466		-0.08682	0.00871		
0.425	-0.06625	-0.22361		-0.06625	0.01146		
0.450	-0.04567	-0.22113		-0.04567	0.01502		
0.475	-0.02510	-0.21722		-0.02510	0.01961		
0.500	-0.00452	-0.21185		-0.00452	0.02503		
0.525	0.01605	-0.20501		0.01605	0.03139		
0.550	0.03663	-0.19664		0.03663	0.03869		
0.575	0.05720	-0.18671		0.05720	0.04698		
0.600	0.07778	-0.17516		0.07778	0.05629		
0.625	0.09835	-0.16192		0.09835	0.06665		
0.650	0.11893	-0.14690		0.11893	0.07012		
0.675	0.13950	-0.13001		0.13950	0.09076		
0.700	0.16008	-0.11113		0.16008	0.10462		
0.725	0.18065	-0.09099		0.18065	0.11979		
0.750	0.20123	-0.06672		0.20123	0.13637		
0.775	0.22180	-0.04076		0.22180	0.15447		
0.800	0.24238	-0.01198		0.24238	0.17424		
0.825	0.26295	0.02064		0.26295	0.19584		
0.850	0.28353	0.05566		0.28353	0.21949		
0.875	0.30410	0.09529		0.30410	0.24549		
0.900	0.32468	0.13938		0.32468	0.27420		
0.910	0.33291	0.15836		0.33291	0.28656		
0.920	0.34114	0.17815		0.34114	0.29947		
0.930	0.34937	0.19879		0.34937	0.31298		
0.940	0.35760	0.22029		0.35760	0.32716		
0.950	0.36583	0.24270		0.36583	0.34206		
0.960	0.37406	0.26603		0.37406	0.35777		
0.970	0.38229	0.29031		0.38229	0.37439		
0.980	0.39052	0.31556		0.39052	0.39204		
0.990	0.39875	0.34182		0.39875	0.41087		
1.000	0.40698	0.36908	0.37090	0.40698	0.43110	0.37090	

NO. 1 CORE VTOUR TITLE - SSM FT FINAL 2V...R.J. ROMEY...6.  
 TD 0 REV. 0 PART NO. END NO. DA.: 08/19/87 TIME 11:46:42  
 SUBTITLE MEAN HOT RADIUS = 4.64925 COLD RADIUS = 4.63600 THERMAL SHRINK FACTOR = 1.00000

PRETMIST NOT USED FOR TD PRINTOUT.

PCT X	X TOP	V TOP	(CIRCLE)	X BOT	Y BOT	(CIRCLE)
0.0	-0.31082	-0.04658	-0.03862	-0.31082	-0.01758	-0.03862
0.010	-0.32537	-0.05060		-0.32537	-0.01931	-0.02680
0.020	-0.31991	-0.05646		-0.31991	-0.02100	-0.02380
0.030	-0.31446	-0.06215		-0.31446	-0.02266	-0.02312
0.040	-0.30901	-0.06767		-0.30901	-0.02429	
0.050	-0.30355	-0.07302		-0.30355	-0.02598	
0.060	-0.29810	-0.07818		-0.29810	-0.02744	
0.070	-0.29265	-0.08317		-0.29265	-0.02897	L.E. CIRCLE (X,Y,R)
0.080	-0.28720	-0.08729		-0.28720	-0.03045	L.E. CIRCLE (X,Y,R)
0.090	-0.28174	-0.09265		-0.28174	-0.03198	L.E. CIRCLE (X,Y,R)
0.100	-0.27629	-0.09714		-0.27629	-0.03327	L.E. TOP TANG. PT. (X,Y)
0.125	-0.26266	-0.10769		-0.26266	-0.03554	L.E. BOTTOM TANG. PT. (X,Y)
0.150	-0.24903	-0.11720		-0.24903	-0.03967	T.E. TOP TANG. PT. (X,Y)
0.175	-0.23559	-0.12604		-0.23559	-0.04202	T.E. BOTTOM TANG. PT. (X,Y)
0.200	-0.22176	-0.13394		-0.22176	-0.04419	
0.225	-0.20813	-0.14102		-0.20813	-0.04600	NOSE POINT (X,Y)
0.250	-0.19450	-0.14728		-0.19450	-0.04746	TAIL POINT (X,Y)
0.275	-0.18086	-0.15272		-0.18086	-0.04860	
0.300	-0.16723	-0.15737		-0.16723	-0.04939	
0.325	-0.15360	-0.16124		-0.15360	-0.04985	
0.350	-0.13997	-0.16433		-0.13997	-0.04997	
0.375	-0.12633	-0.16666		-0.12633	-0.04975	
0.400	-0.11270	-0.16822		-0.11270	-0.04918	
0.425	-0.09907	-0.16901		-0.09907	-0.04828	
0.450	-0.08564	-0.16904		-0.08564	-0.04703	
0.475	-0.07180	-0.16830		-0.07180	-0.04565	
0.500	-0.05317	-0.16680		-0.05317	-0.04352	
0.525	-0.04454	-0.16452		-0.04454	-0.04125	
0.550	-0.03021	-0.16148		-0.03021	-0.03863	
0.575	-0.01727	-0.15765		-0.01727	-0.03565	
0.600	-0.00364	-0.15304		-0.00364	-0.03232	
0.625	0.00999	-0.14763		0.00999	-0.02862	
0.650	0.02362	-0.14191		0.02362	-0.02456	
0.675	0.03726	-0.13436		0.03726	-0.02012	
0.700	0.05089	-0.12647		0.05089	-0.01610	
0.725	0.06452	-0.11772		0.06452	-0.01010	
0.750	0.07815	-0.10808		0.07815	-0.00450	
0.775	0.09179	-0.09751		0.09179	0.00150	
0.800	0.10542	-0.08599		0.10542	0.00791	
0.825	0.11905	-0.07347		0.11905	0.01476	
0.850	0.13268	-0.05990		0.13268	0.02294	
0.875	0.14632	-0.04525		0.14632	0.02977	
0.900	0.15995	-0.02944		0.15995	0.03796	
0.910	0.16540	-0.02279		0.16540	0.04137	
0.920	0.17086	-0.01593		0.17086	0.04486	
0.930	0.17631	-0.00886		0.17631	0.04802	
0.940	0.18176	0.00156		0.18176	0.05206	
0.950	0.18721	0.00596		0.18721	0.05578	
0.960	0.19267	0.01371		0.19267	0.05959	
0.970	0.19812	0.02170		0.19812	0.06274	
0.980	0.20357	0.02996		0.20357	0.06324	
0.990	0.20903	0.03648		0.20903	0.06115	
1.000	0.21448	0.04728	0.05082	0.21448	0.05082	

EXTERNAL 1 OUR  
TD 0 .J REV. 0 PART NO.  
SUBTITLE 1/4 TIP

TITLE - SSME FT FINAL 2V...R.J. ROMEY...6  
END NO.  
HOT RADIUS = 4.91387

DATE 08/19/87 TIME 11:46:42  
COLD RADIUS = 4.89800 CYLINDRICAL  
THERMAL SHRINK FACTOR = 1.00000

PRETHIS NOT USED FOR PRINTOUT.

PCT X	X TOP	Y TOP	(CIRCLE)	X BOT	Y BOT	(CIRCLE)
0.0	-0.44502	-0.08405	-0.07325	-0.45802	-0.05840	-0.07325
0.010	-0.43627	-0.10210	-0.43627	-0.04301	-0.04538	
0.020	-0.42753	-0.11697	-0.42753	-0.03680	-0.03582	
0.030	-0.41878	-0.12868	-0.41878	-0.02976	-0.02999	
0.040	-0.41004	-0.13863	-0.41004	-0.02645		
0.050	-0.40129	-0.14754	-0.40129	-0.02431		
0.060	-0.39255	-0.15586	-0.39255	-0.02306		
0.070	-0.38380	-0.16377	-0.38380	-0.02251		
0.080	-0.37506	-0.17135	-0.37506	-0.02255		
0.090	-0.36632	-0.17861	-0.36632	-0.02310		
0.100	-0.35757	-0.18556	-0.35757	-0.02412		
0.125	-0.33571	-0.19163	-0.33571	-0.02840		
0.150	-0.31385	-0.21594	-0.31385	-0.03362		
0.175	-0.29198	-0.22858	-0.29198	-0.03763		
0.200	-0.27012	-0.23593	-0.27012	-0.04101		
0.225	-0.24826	-0.24916	-0.24826	-0.04360		
0.250	-0.22640	-0.25724	-0.22640	-0.04540		
0.275	-0.20453	-0.26388	-0.20453	-0.04643		
0.300	-0.18267	-0.26914	-0.18267	-0.04669		
0.325	-0.16081	-0.27303	-0.16081	-0.04619		
0.350	-0.13895	-0.27559	-0.13895	-0.04623		
0.375	-0.11708	-0.27681	-0.11708	-0.04291		
0.400	-0.09522	-0.27671	-0.09522	-0.04013		
0.425	-0.07336	-0.27528	-0.07336	-0.03658		
0.450	-0.05150	-0.27251	-0.05150	-0.03225		
0.475	-0.02963	-0.26840	-0.02963	-0.02714		
0.500	-0.00777	-0.26290	-0.00777	-0.02123		
0.525	0.01409	-0.25601	0.01409	-0.01450		
0.550	0.03595	-0.24766	0.03595	-0.00692		
0.575	0.05782	-0.23782	0.05782	0.00152		
0.600	0.07948	-0.22643	0.07948	0.01086		
0.625	0.10154	-0.21340	0.10154	0.02114		
0.650	0.12340	-0.19864	0.12340	0.03240		
0.675	0.14527	-0.18204	0.14527	0.04470		
0.700	0.16713	-0.16347	0.16713	0.05808		
0.725	0.18899	-0.14274	0.18899	0.07264		
0.750	0.21085	-0.11963	0.21085	0.08445		
0.775	0.23272	-0.09385	0.23272	0.10564		
0.800	0.25458	-0.06507	0.25458	0.12432		
0.825	0.27644	-0.03289	0.27644	0.14466		
0.850	0.29830	0.00302	0.29830	0.16687		
0.875	0.32017	0.04296	0.32017	0.19124		
0.900	0.34203	0.08714	0.34203	0.21812		
0.910	0.35077	0.10604	0.35077	0.22970		
0.920	0.35952	0.12565	0.35952	0.24179		
0.930	0.36826	0.14599	0.36826	0.25447		
0.940	0.37701	0.16705	0.37701	0.26778		
0.950	0.38575	0.18886	0.38575	0.28180		
0.960	0.39450	0.21139	0.39450	0.29662		
0.970	0.40324	0.23467	0.40324	0.31235		
0.980	0.41199	0.25869	0.41199	0.32915		
0.990	0.42073	0.28348	0.42073	0.34720		
1.000	0.42948	0.30900	0.42948	0.36676		

NO. 1 CDR NTOUR  
TD 0 REV. 0 PART NO. TITLE - SSHE FT FINAL 2V...R.J. ROMEY...  
SUBTITLE 1/4 TIP END NO. DA.: 08/19/87 TIME 11:46:42  
COLD RADIUS = 4.91367 COLD RADIUS = 4.89800 THERMAL SHRINK FACTOR = 1.000000

7..  
CYLINDRICAL

PENTMIST NOT USED FOR TD PRINTOUT.

PCT X	X TOP	Y TOP	(CIRCLE)	X BOT	Y BOT	(CIRCLE)
0.0	-0.35975	-0.11021	-0.10276	-0.35375	-0.09163	-0.10276
0.010	-0.35377	-0.11579	-0.35377	-0.08293	-0.08976	
0.020	-0.34778	-0.12120	-0.34778	-0.08420	-0.08643	
0.030	-0.34180	-0.12646	-0.34180	-0.08545	-0.08565	
0.040	-0.33582	-0.13156	-0.33582	-0.08666		
0.050	-0.32983	-0.13649	-0.32983	-0.08784		
0.060	-0.32385	-0.14125	-0.32385	-0.08898		
0.070	-0.31786	-0.14585	-0.31786	-0.09010		
0.080	-0.31188	-0.15029	-0.31188	-0.09118		
0.090	-0.30590	-0.1556	-0.30590	-0.09222		
0.100	-0.29991	-0.15868	-0.29991	-0.09323		
0.125	-0.28495	-0.16831	-0.28495	-0.09555		
0.150	-0.26999	-0.17705	-0.26999	-0.09756		
0.175	-0.25503	-0.18494	-0.25503	-0.09922		
0.200	-0.24007	-0.19291	-0.24007	-0.10051		
0.225	-0.22511	-0.19930	-0.22511	-0.10145		
0.250	-0.21015	-0.20381	-0.21015	-0.10206		
0.275	-0.19519	-0.20853	-0.19519	-0.10237		
0.300	-0.18023	-0.21250	-0.18023	-0.10235		
0.325	-0.16527	-0.21571	-0.16527	-0.10202		
0.350	-0.15031	-0.21819	-0.15031	-0.10134		
0.375	-0.13535	-0.21993	-0.13535	-0.10039		
0.400	-0.12039	-0.22095	-0.12039	-0.09908		
0.425	-0.10543	-0.22222	-0.10543	-0.09746		
0.450	-0.09047	-0.22277	-0.09047	-0.09551		
0.475	-0.07552	-0.21957	-0.07552	-0.09325		
0.500	-0.06056	-0.21165	-0.06056	-0.09066		
0.525	-0.04560	-0.21497	-0.04560	-0.08775		
0.550	-0.03064	-0.21156	-0.03064	-0.08450		
0.575	-0.01563	-0.20335	-0.01563	-0.08092		
0.600	-0.00072	-0.20239	-0.00072	-0.07700		
0.625	0.01424	-0.19664	0.01424	-0.07274		
0.650	0.02920	-0.19008	0.02920	-0.06812		
0.675	0.04416	-0.18269	0.04416	-0.06315		
0.700	0.05912	-0.17444	0.05912	-0.05782		
0.725	0.07408	-0.16532	0.07408	-0.05212		
0.750	0.08904	-0.15527	0.08904	-0.04603		
0.775	0.10400	-0.14426	0.10400	-0.03957		
0.800	0.11896	-0.13224	0.11896	-0.03271		
0.825	0.13392	-0.11914	0.13392	-0.02543		
0.850	0.14888	-0.10488	0.14888	-0.01772		
0.875	0.16384	-0.08941	0.16384	-0.00959		
0.900	0.17880	-0.07260	0.17880	-0.00101		
0.910	0.18479	-0.06549	0.18479	0.00256		
0.920	0.19077	-0.05913	0.19077	0.00620		
0.930	0.19675	-0.05052	0.19675	0.00991		
0.940	0.20274	-0.04265	0.20274	0.01371		
0.950	0.20872	-0.03450	0.20872	0.01759		
0.960	0.21471	-0.02609	0.21471	0.02155		
0.970	0.22069	-0.01739	0.22069	0.02541		
0.980	0.22667	-0.00840	0.22667	0.02661		
0.990	0.23266	0.00909	0.23266	0.02476		
1.000	0.23864	0.01049	0.23864	0.02405		

EXTERNAL ! CDR 7... TITLE - SSME FT FINAL 2V...R.J. ROMEY...6  
 TD 0 .J REV. 0 PART NO. END NO. DATE 09/19/87 TIME 11:46:42  
 SUBTITLE TIP HOT RADIUS = 5.17850 COLD RADIUS = 5.16000 THERMAL SHRINK FACTOR = 1.00000

PRETMIST NOT USED FOR TD PRINTOUT.

PCT X	X TOP	Y TOP	(CIRCLE)	X BOT	Y BOT	(CIRCLE)
0.0	-0.47602	-0.12121	-0.15667	-0.47602	-0.16200	-0.15967
0.010	-0.46476	-0.15843		-0.46476	-0.13017	-0.13111
0.020	-0.45550	-0.20553		-0.45550	-0.12146	-0.12156
0.030	-0.44624	-0.21353		-0.44624	-0.11586	
0.040	-0.43698	-0.22282		-0.43698	-0.11195	
0.050	-0.42772	-0.23097		-0.42772	-0.10920	
0.060	-0.41846	-0.23826		-0.41846	-0.10730	
0.070	-0.40920	-0.24506		-0.40920	-0.10609	
0.080	-0.39994	-0.25155		-0.39994	-0.10545	
0.090	-0.39068	-0.25774		-0.39068	-0.10531	
0.100	-0.38142	-0.26365		-0.38142	-0.10562	
0.125	-0.35827	-0.27723		-0.35827	-0.10792	
0.150	-0.33512	-0.28921		-0.33512	-0.11019	
0.175	-0.31197	-0.29970		-0.31197	-0.11180	
0.200	-0.28882	-0.30876		-0.28882	-0.11276	
0.225	-0.26567	-0.31647		-0.26567	-0.11310	
0.250	-0.24252	-0.32249		-0.24252	-0.11282	
0.275	-0.21937	-0.32805		-0.21937	-0.11193	
0.300	-0.19622	-0.33196		-0.19622	-0.1045	
0.325	-0.17307	-0.33472		-0.17307	-0.10337	
0.350	-0.14992	-0.33627		-0.14992	-0.10570	
0.375	-0.12677	-0.33665		-0.12677	-0.10243	
0.400	-0.10362	-0.33596		-0.10362	-0.09856	
0.425	-0.08047	-0.33390		-0.08047	-0.09410	
0.450	-0.05732	-0.33076		-0.05732	-0.09203	
0.475	-0.03417	-0.32642		-0.03417	-0.08334	
0.500	-0.01102	-0.32085		-0.01102	-0.07703	
0.525	0.01213	-0.31102		0.01213	-0.07007	
0.550	0.03524	-0.30586		0.03524	-0.06264	
0.575	0.05643	-0.29639		0.05643	-0.05616	
0.600	0.08158	-0.28548		0.08158	-0.04512	
0.625	0.10473	-0.27506		0.10473	-0.03536	
0.650	0.12788	-0.25902		0.12788	-0.02682	
0.675	0.15103	-0.24325		0.15103	-0.01346	
0.700	0.17418	-0.22553		0.17418	-0.00123	
0.725	0.19733	-0.20580		0.19733	0.01195	
0.750	0.22068	-0.18364		0.22068	0.02613	
0.775	0.24363	-0.15876		0.24363	0.04143	
0.800	0.26678	-0.13072		0.26678	0.05795	
0.825	0.28993	-0.09916		0.28993	0.07584	
0.850	0.31138	-0.06380		0.31138	0.09522	
0.875	0.33623	-0.02457		0.33623	0.11656	
0.900	0.35926	0.01861		0.35926	0.13999	
0.920	0.36864	0.03660		0.36864	0.15008	
0.920	0.37720	0.05532		0.37720	0.16063	
0.930	0.38716	0.07454		0.38716	0.17170	
0.940	0.39642	0.09424		0.39642	0.18334	
0.950	0.40568	0.11460		0.40568	0.19565	
0.960	0.41494	0.13497		0.41494	0.20871	
0.970	0.42260	0.15594		0.42260	0.22264	
0.980	0.43346	0.17777		0.43346	0.23763	0.23440
0.990	0.44272	0.19895		0.44272	0.25390	0.23552
1.000	0.45198	0.22094	0.22345	0.45198	0.27181	0.22345

NO. 1 COR' MTOUR  
TD 6 J REV.  
SUBTITLE TIP

TITLE - SSMF FT FINAL 2V...R.J. RDNEY...6  
END NO. DA-- 08/19/87 TIME 11:46:42  
HOT RADIUS = 5.17850 COLD RADIUS = 5.16000 THERMAL SHRINK FACTOR = 1.00000

PRETMIST NOT USED FOR TD PRINTOUT.

PCT	X	X TOP	Y TOP	(CIRCLE)	X BOT	Y BOT	(CIRCLE)
0.0	-0.38872	-0.19064	-0.18160	-0.38872	-0.18112	-0.18160	
0.010	-0.38220	-0.19574	-0.19569	-0.38220	-0.19585	-0.19550	
0.020	-0.37569	-0.20048	-0.20048	-0.37569	-0.16250	-0.16392	
0.030	-0.36917	-0.20506	-0.20506	-0.36917	-0.16312	-0.16313	
0.040	-0.35245	-0.20949	-0.20949	-0.35245	-0.16371		
0.050	-0.35613	-0.21376	-0.21376	-0.35613	-0.16428		
0.060	-0.34962	-0.21788	-0.21788	-0.34962	-0.16482		
0.070	-0.34310	-0.22185	-0.22185	-0.34310	-0.16533		
0.080	-0.33658	-0.22564	-0.22564	-0.33658	-0.16582		
0.090	-0.33007	-0.22931	-0.22931	-0.33007	-0.16626		
0.100	-0.32355	-0.23282	-0.23282	-0.32355	-0.16671		
0.125	-0.30726	-0.24095	-0.24095	-0.30726	-0.16763		
0.150	-0.29097	-0.24892	-0.24892	-0.29097	-0.16830		
0.175	-0.27467	-0.25472	-0.25472	-0.27467	-0.16866		
0.200	-0.25838	-0.26046	-0.26046	-0.25838	-0.16870		
0.225	-0.24209	-0.26495	-0.26495	-0.24209	-0.16894		
0.250	-0.22580	-0.26975	-0.26975	-0.22580	-0.16782		
0.275	-0.20950	-0.27333	-0.27333	-0.20950	-0.16707		
0.300	-0.19321	-0.27622	-0.27622	-0.19321	-0.16598		
0.325	-0.17692	-0.27842	-0.27842	-0.17692	-0.16461		
0.350	-0.16063	-0.27947	-0.27947	-0.16063	-0.16296		
0.375	-0.14433	-0.28085	-0.28085	-0.14433	-0.16103		
0.400	-0.12804	-0.28108	-0.28108	-0.12804	-0.15891		
0.425	-0.11175	-0.28064	-0.28064	-0.11175	-0.15632		
0.450	-0.09546	-0.27954	-0.27954	-0.09546	-0.15356		
0.475	-0.07916	-0.27776	-0.27776	-0.07916	-0.15052		
0.500	-0.06287	-0.27535	-0.27535	-0.06287	-0.14719		
0.525	-0.04658	-0.27224	-0.27224	-0.04658	-0.14359		
0.550	-0.03029	-0.26864	-0.26864	-0.03029	-0.13969		
0.575	-0.01399	-0.26394	-0.26394	-0.01399	-0.13551		
0.600	0.00230	-0.25872	-0.25872	0.00230	-0.13102		
0.625	0.01859	-0.25276	-0.25276	0.01859	-0.12624		
0.650	0.03689	-0.24604	-0.24604	0.03689	-0.12115		
0.675	0.05118	-0.23852	-0.23852	0.05118	-0.11574		
0.700	0.06747	-0.23017	-0.23017	0.06747	-0.11002		
0.725	0.08376	-0.22096	-0.22096	0.08376	-0.10396		
0.750	0.10005	-0.21083	-0.21083	0.10005	-0.09752		
0.775	0.11635	-0.19973	-0.19973	0.11635	-0.09087		
0.800	0.13264	-0.18760	-0.18760	0.13264	-0.08376		
0.825	0.14893	-0.17434	-0.17434	0.14893	-0.07633		
0.850	0.16522	-0.15283	-0.15283	0.16522	-0.06850		
0.875	0.18152	-0.14400	-0.14400	0.18152	-0.06028		
0.900	0.19781	-0.12666	-0.12666	0.19781	-0.05165		
0.910	0.20433	-0.11927	-0.11927	0.20433	-0.04808		
0.920	0.21084	-0.11160	-0.11160	0.21084	-0.04444		
0.930	0.21736	-0.10363	-0.10363	0.21736	-0.04072		
0.940	0.22388	-0.09536	-0.09536	0.22388	-0.03693		
0.950	0.23039	-0.08677	-0.08677	0.23039	-0.03306		
0.960	0.23691	-0.07797	-0.07797	0.23691	-0.02911		
0.970	0.24343	-0.06865	-0.06865	0.24343	-0.02508		
0.980	0.24995	-0.05910	-0.05910	0.24995	-0.02097		
0.990	0.25646	-0.04924	-0.04924	0.25646	-0.01677		
1.000	0.26298	-0.03905	-0.03905	0.26298	-0.01249		

**GRAPH PAPER** - certain conditions -  
Buffalo, New York - Printed in U.S.A.

SHAW 15-16-17-18-19-20 DASH AS 0013-68

SISTEMAS DE INFORMACIÓN

WOT GAGGVS RADVIS

A. 1st AGE FLOW AREA, HR.

REQUIRED 14-3129 11-115

ACTUAL 12.30.12

卷之三

5.5

R. 8/20/87

MEDLINE DESIGN STREET 600' x 100' = 19832 sf  
 PERCH CREEK ACRE = 1/2 1/2 3/4 lot  
 = 12.5875 sf land  
 MUL CREEK 200' x 30' = 6000 sf

~HOLY CHANGING BOUNDARIES~

PB24 UTILITY PROGRAM - FLOW AREA CALCULATION

SOME FT FINAL CV...R.J. ROWEY...6-9-87...  
HOT TO COLD CONVERSION RADII

HOT COLD  
4.12000 4.11200  
5.17850 5.16000

RETAGGER ANGLE DEGREES = 0.0 RADIANS = 0.0  
PLATFORM RADII LE ID = 0.0 LE OD = 0.0  
TE ID = 0.0 TE OD = 0.0  
GAGING RADII INNER = 4.12000 OUTER = 5.17028

NUMBER OF VANE FOR GAGING = 54  
STAGGER IN DEGREES IS -3.00 TO 3.00 IN INCREMENTS OF 0.50  
IN CLASS IS -6 TO 6

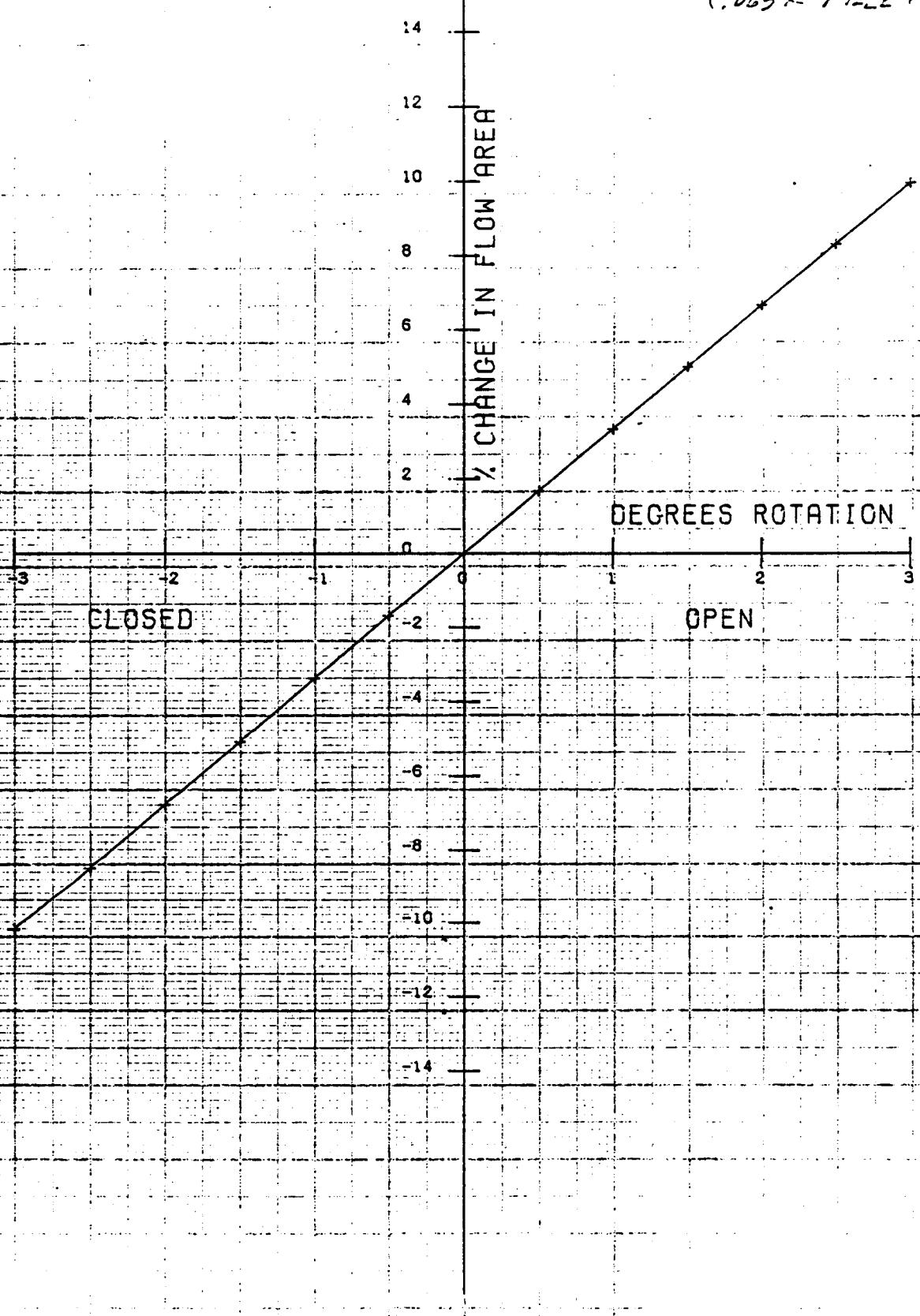
TOLER = 0.0

STAGGER (DEGREES)	HOT FLOW (SQ IN)	( CHANGE FLOW AREA (SQ IN)
-3.00000	11.11811	-10.19512
-2.50000	11.35054	-8.47852
-2.00000	11.54225	-6.76846
-1.50000	11.75204	-5.06624
-1.00000	11.96304	-3.37035
-0.50000	12.17212	-1.68158
0.0	12.38050	0.0
0.50000	12.58761	1.67452
1.00000	12.79402	3.34773
1.50000	12.99955	5.00189
2.00000	13.20415	6.65654
2.50000	13.40787	8.30002
3.00000	13.61106	9.93801

NOMINAL FLOW AREA - SQ. IN.

HOT - 12.380 UNBLOCKED 12.1963 BLOCKED

COLD - 12.272 UNBLOCKED 12.0876 BLOCKED  
(.063 R FILLETS)



SSME FT FL... 2V...R.J. ROMEY...6-9-87...  
 OPERATING CONDITION 1 109 PCT...ADP...R.J. ROMEY...6-10-87...  
 MAE = .159.0 MMX = 0.0 MXT = 36.1 MXT = 164.4

RPM = 0.	MVR = 0.0	MTH = 27.9	MFT = 111.5	NET BENDING		
ZS	RADIUS	SIG P/A	SHRD P/A	LE	TE	CONV
0	4.1220	0.	0.	0.	0.	0.
10	4.2229	0.	0.	509.	439.	-460.
20	4.3258	0.	0.	1636.	1603.	-1649.
30	4.4286	0.	0.	3809.	3353.	-3415.
40	4.5315	0.	0.	6355.	5637.	-5692.
50	4.6344	0.	0.	9470.	8469.	-8549.
60	4.7373	0.	0.	13192.	11908.	-12053.
70	4.8402	0.	0.	17567.	16011.	-16299.
80	4.9630	0.	0.	22601.	20801.	-21355.
90	5.0459	0.	0.	28252.	26249.	-27247.
100	5.1488	0.	0.	34410.	32255.	-33920.
ZS	RADIUS	XOFF	YOFF	LE	TE	GAS BENDING
ZS	RADIUS	AREA	PULL	LE	TE	CONV
0	4.1220	0.0849	0.0	0.	0.	0.
10	4.2229	0.0899	0.0	0.	0.	0.
20	4.3258	0.0943	0.0	0.	0.	0.
30	4.4286	0.0973	-0.0142	3509.	3353.	-3415.
40	4.5315	0.0980	-0.0089	6355.	5637.	-5692.
50	4.6344	0.0980	0.0026	9470.	8469.	-8549.
60	4.7373	0.0972	0.0201	13192.	11908.	-12053.
70	4.8402	0.0957	0.0421	17567.	16011.	-16299.
80	4.9630	0.0937	0.0671	22601.	20801.	-21355.
90	5.0459	0.0913	0.0940	28252.	26249.	-27247.
100	5.1488	-0.0013	0.1212	34410.	32255.	-33920.
ZS	RADIUS	MXT	MTH	M90	M90	THETAN
ZS	RADIUS	AREA	PULL	LE	TE	CONV
0	4.1220	0.0849	0.0	0.	0.	0.
10	4.2229	0.0899	0.0	0.	0.	0.
20	4.3258	0.0943	0.0	0.	0.	0.
30	4.4286	0.0973	0.0	0.	0.	0.
40	4.5315	0.1016	0.0	0.	0.	0.
50	4.6344	0.1044	0.0	0.	0.	0.
60	4.7373	0.1065	0.0	0.	0.	0.
70	4.8402	0.1081	0.0	0.	0.	0.
80	4.9630	0.1094	0.0	0.	0.	0.
90	5.0459	0.1103	0.0	0.	0.	0.
100	5.1488	0.1112	0.0	0.	0.	0.

SSME FT FLUID 2V...R.J. ROMEY...6-9-87  
 DENSITY = 0.31100 WEIGHTING RADIU INNER = 4.1200 OUTER = 5.1488  
 SHROUD VOLUME = 0.0  
 SHROUD THICKNESS = 0.0  
 SHROUD MISALIGNMENT = 0.0 RADIUS OF SHROUD = 0.0  
 HEIGHT OF AIRFOIL = 0.03267 HEIGHT OF SHROUD = 0.0  
 TOTAL HEIGHT = 1.76436 NUMBER OF VANES = 54

SUMMARY OF SECTION PROPERTIES

ZS	RADIUS	AREA	IMIN	IMAX	THETA	XBAR	YBAR
0	4.1200	0.0869 0.5182E-03	0.3633E-02	-18.70	-0.0000	-0.0000	
10	4.2229	0.0899 0.6379E-03	0.4207E-02	-20.30	0.0033	-0.0103	
20	4.3258	0.0943 0.7507E-03	0.4705E-02	-21.54	0.0057	-0.0154	
30	4.4286	0.0983 0.8490E-03	0.5354E-02	-22.39	0.0072	-0.0149	
40	4.5315	0.1016 0.9265E-03	0.5897E-02	-22.85	0.0089	-0.0069	
50	4.6344	0.1044 0.9703E-03	0.6398E-02	-22.96	0.0080	0.0028	
60	4.7373	0.1065 0.1002E-02	0.6846E-02	-22.75	0.0072	0.0201	
70	4.8402	0.1081 0.1001E-02	0.7242E-02	-22.31	0.0057	0.0420	
80	4.9430	0.1094 0.2832E-03	0.7597E-02	-21.74	0.0037	0.0671	
90	5.0459	0.1103 0.9566E-03	0.7929E-02	-21.14	0.0013	0.0940	
100	5.1488	0.1112 0.9290E-03	0.8258E-02	-20.57	-0.0013	0.1212	

ZS	RADIUS	K	HAT	AHATDIN	C1	C2
0	4.1200	0.0	0.8844E-04	0.1745	0.7200	0.1563
10	4.2229	0.0	0.1079E-03	0.1781	0.7500	0.1704
20	4.3258	0.0	0.1293E-03	0.1846	0.7600	0.1818
30	4.4286	0.0	0.1523E-03	0.1931	0.7801	0.1898
40	4.5315	0.0	0.1761E-03	0.2066	0.8001	0.1945
50	4.6344	0.0	0.1995E-03	0.2220	0.8201	0.2077
60	4.7373	0.0	0.2223E-03	0.2403	0.8401	0.1943
70	4.8402	0.0	0.2448E-03	0.2602	0.8602	0.2055
80	4.9430	0.0	0.2683E-03	0.2832	0.8802	0.2038
90	5.0459	0.0	0.2938E-03	0.3063	0.9002	0.1767
100	5.1488	0.0	0.3227E-03	0.3297	0.9202	0.1903

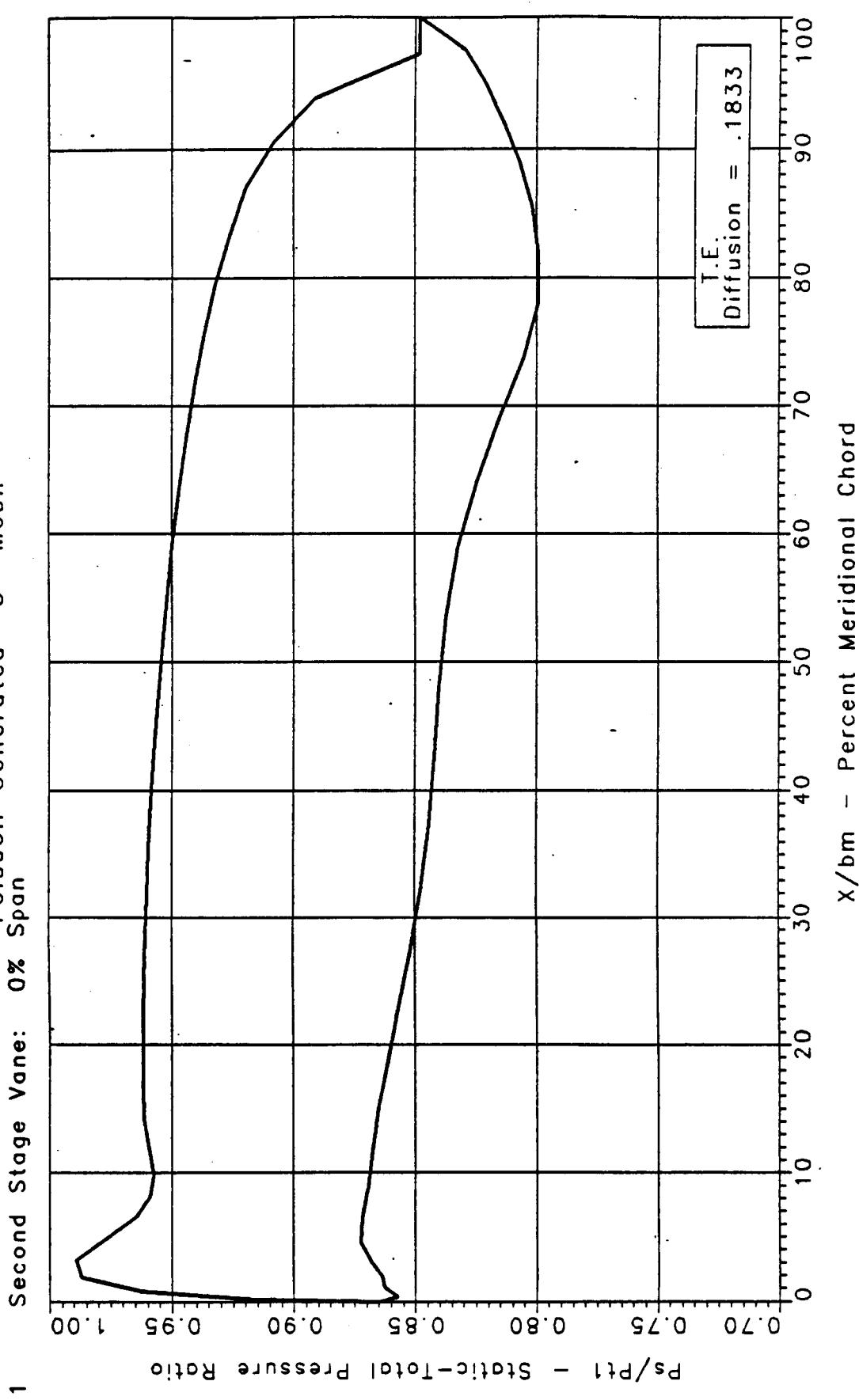
  

ZS	RADIUS	C3	C4	CTE	C4	ALPHA	B
0	4.1200	0.1543	0.2941	0.4200	0.0311	70.06	0.7527
10	4.2229	0.1650	0.3033	0.4400	0.0440	68.50	0.7806
20	4.3258	0.1735	0.3126	0.4594	0.0547	67.35	0.8090
30	4.4286	0.1800	0.3224	0.4759	0.0626	66.54	0.8343
40	4.5315	0.1847	0.3329	0.4898	0.0665	66.06	0.8594
50	4.6344	0.1875	0.3440	0.5011	0.0483	65.66	0.8831
60	4.7373	0.1893	0.3557	0.5098	0.0473	65.91	0.9056
70	4.8402	0.1875	0.3678	0.5168	0.0440	66.16	0.9269
80	4.9430	0.1855	0.3801	0.5228	0.0393	66.52	0.9475
90	5.0459	0.1827	0.3924	0.5286	0.0338	66.93	0.9676
100	5.1488	0.1797	0.4045	0.5346	0.0283	67.35	0.9874

P624 UTILITY PROGRAM - STRESS CALCULATION

SSME FT FINAL 2V...R.J. ROMEY...6-9-87...  
ENGINE OPERATING CONDITION  
NAME SPN TITLE  
1 169.0 0. 109 PCT...ADP...R.J. ROMEY...6-10-87...  
XGBR = 0.0 XGBH = 36.13679 XGBT = 144.43350  
YGBR = 0.0 YGBM = 27.89259 YGBT = 111.47960  
DENSITY = 0.31100 HEIGHITING RADIU INNER = 4.1200 OUTER = 5.1496  
SHROUD VOLUME = 0.0 SHROUD THICKNESS = 0.0  
SHROUD MISALIGNMENT = 0.0 RADIUS OF SHROUD = 0.0

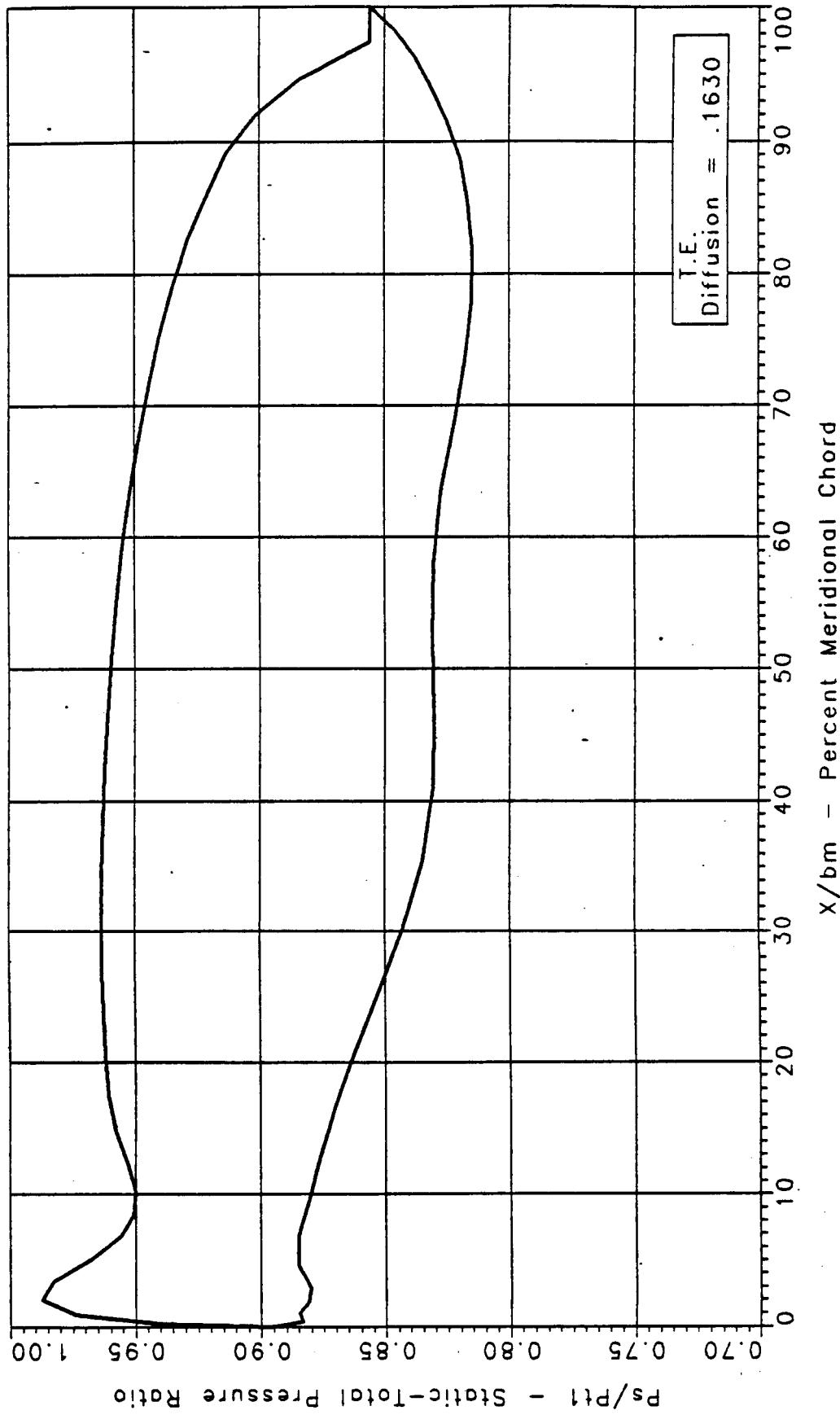
PRATT & WHITNEY  
 SSME ATD Fuel Pump Turbine  
 3-D Pressure Distribution "C" - Mesh  
 Poisson Generated



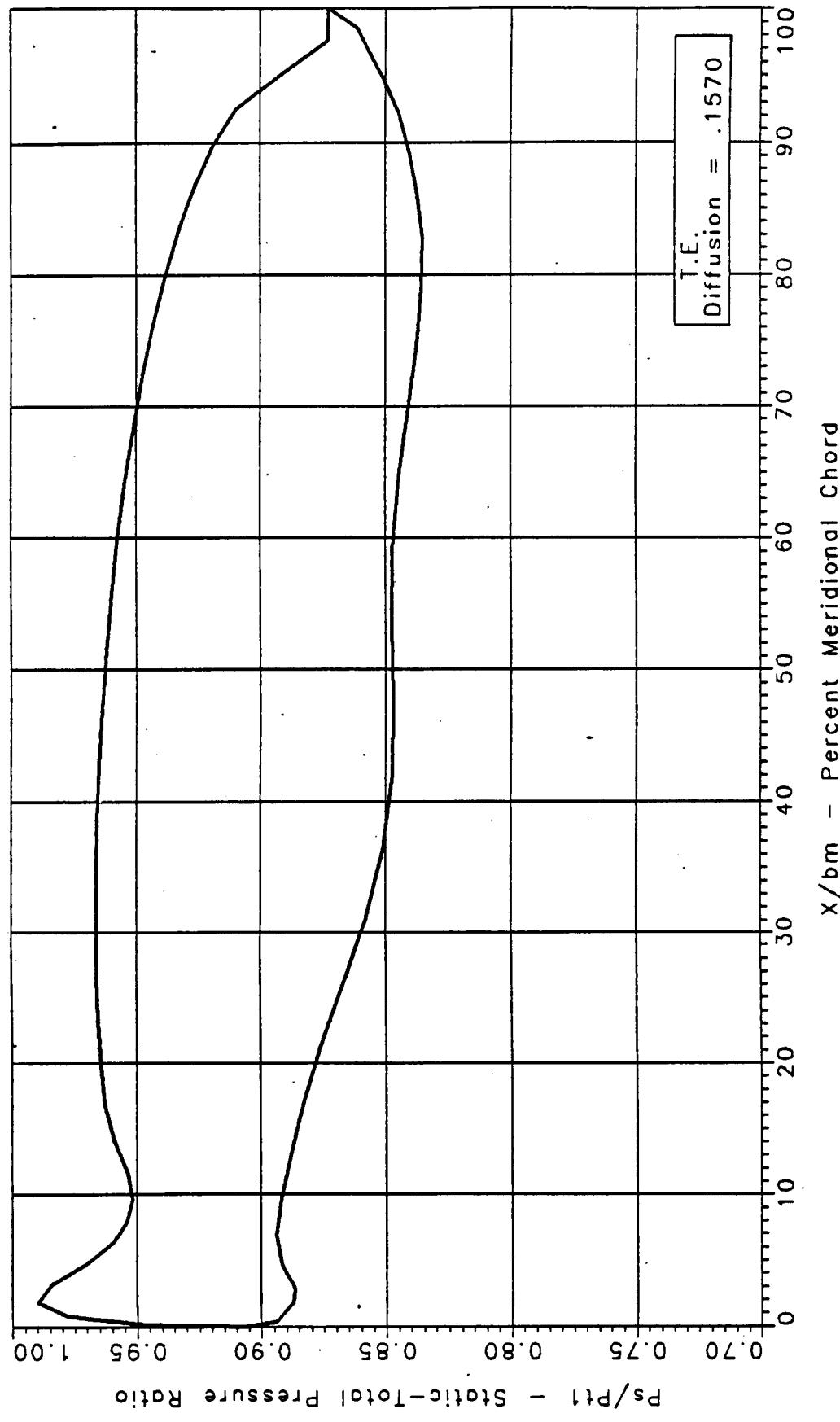
08/20/87  
DL

08/20/87  
DLS

PRATT & WHITNEY  
SSME ATD Fuel Pump Turbine  
3-D Pressure Distribution "C"-Mesh  
Poisson Generated "C"-Mesh  
Span: 25%  
Second Stage Vane: 12

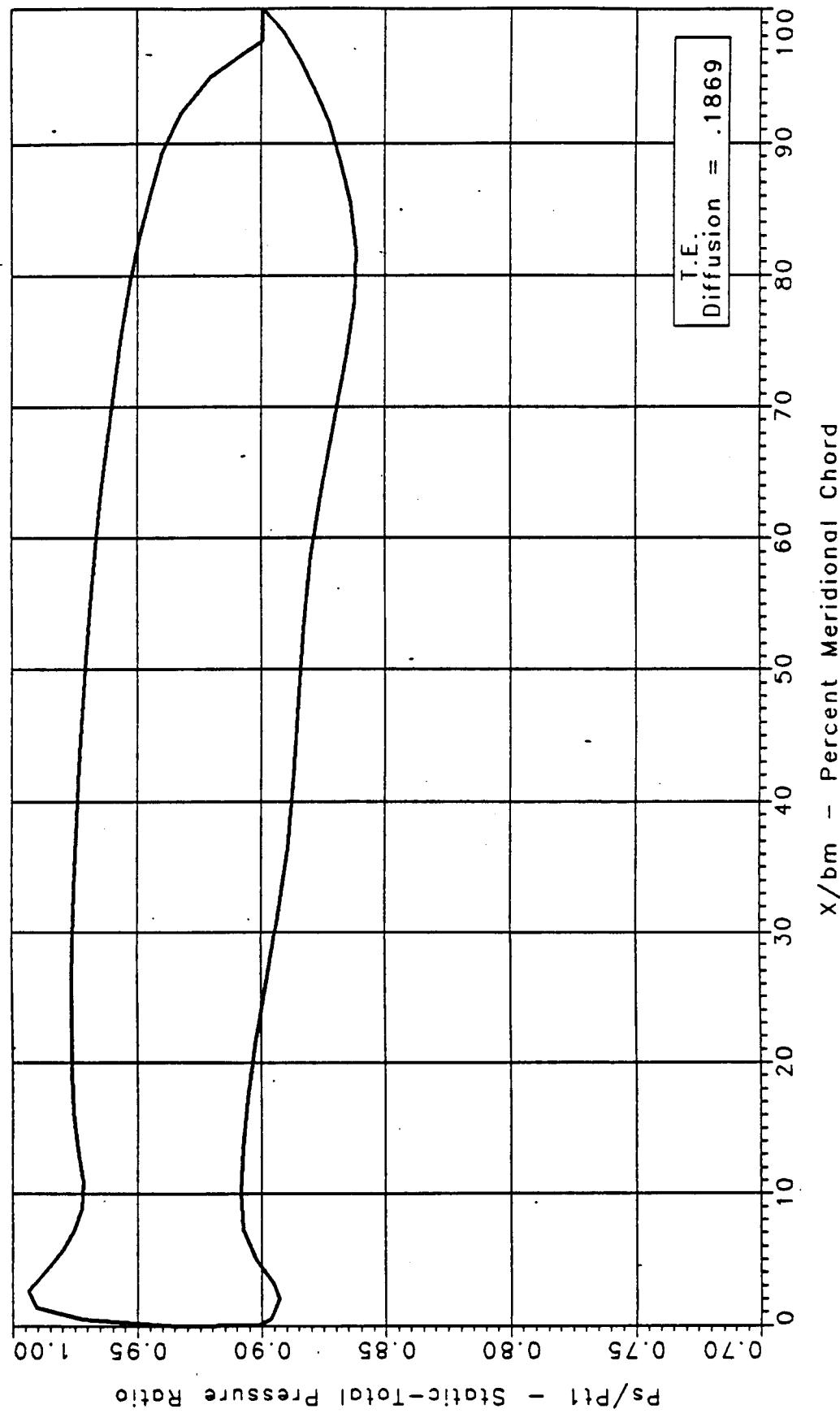


PRATT & WHITNEY  
 SSME ATD Fuel Pump Turbine  
 3-D Pressure Distribution "C"-Mesh  
 Poisson Generated  
 Second Stage Vane: 50% span



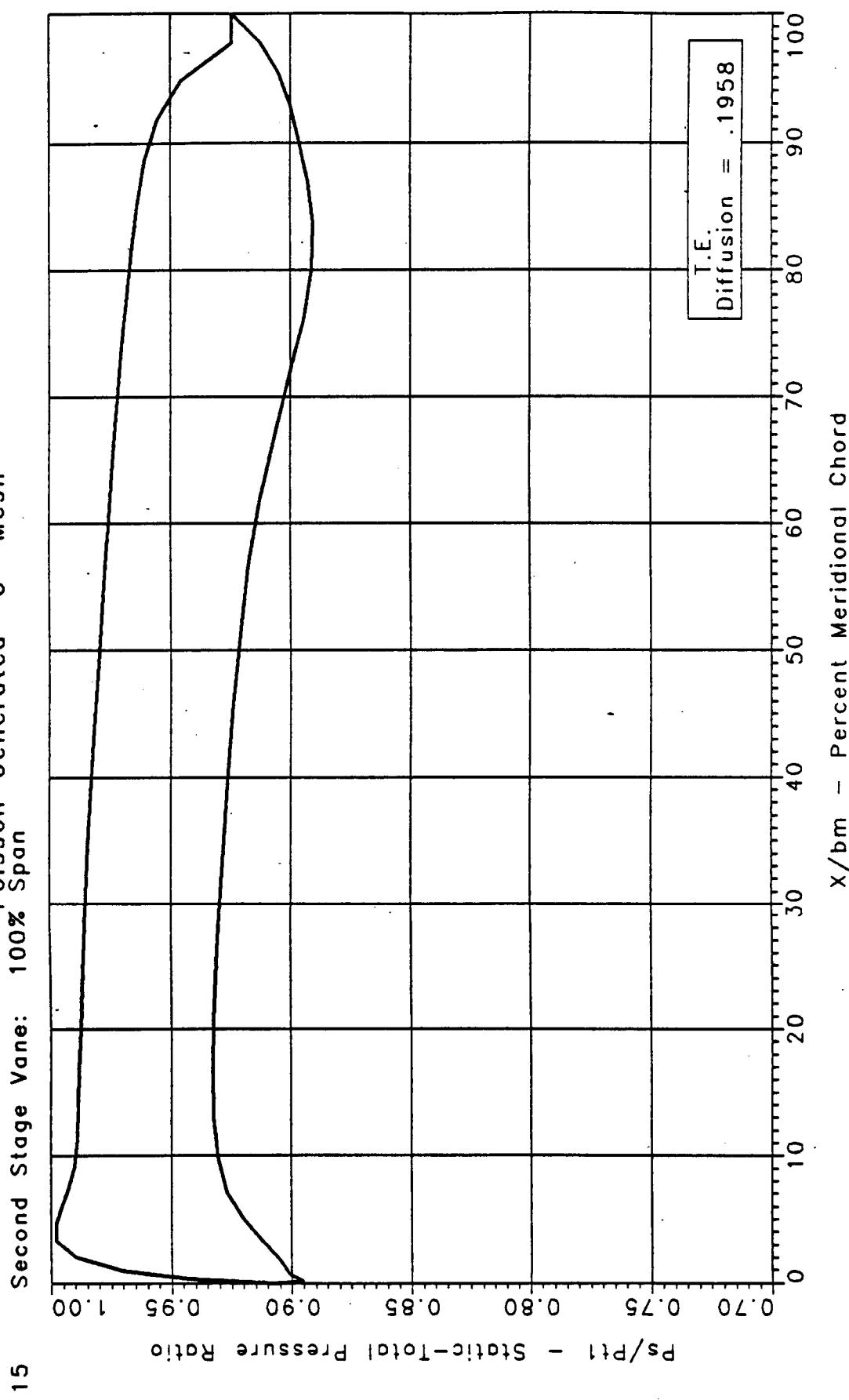
08/20/87  
DLS

PRATT & WHITNEY  
 SSME ATD Fuel Pump Turbine  
 3-D Pressure Distribution "C"-Mesh  
 Poisson Generated "C"-Mesh  
 Second Stage Vane: 75% Span



08/20/87  
 DLS

PRATT & WHITNEY  
SSME ATD Fuel Pump Turbine  
3-D Pressure Distribution "C"-Mesh  
Poisson Generated



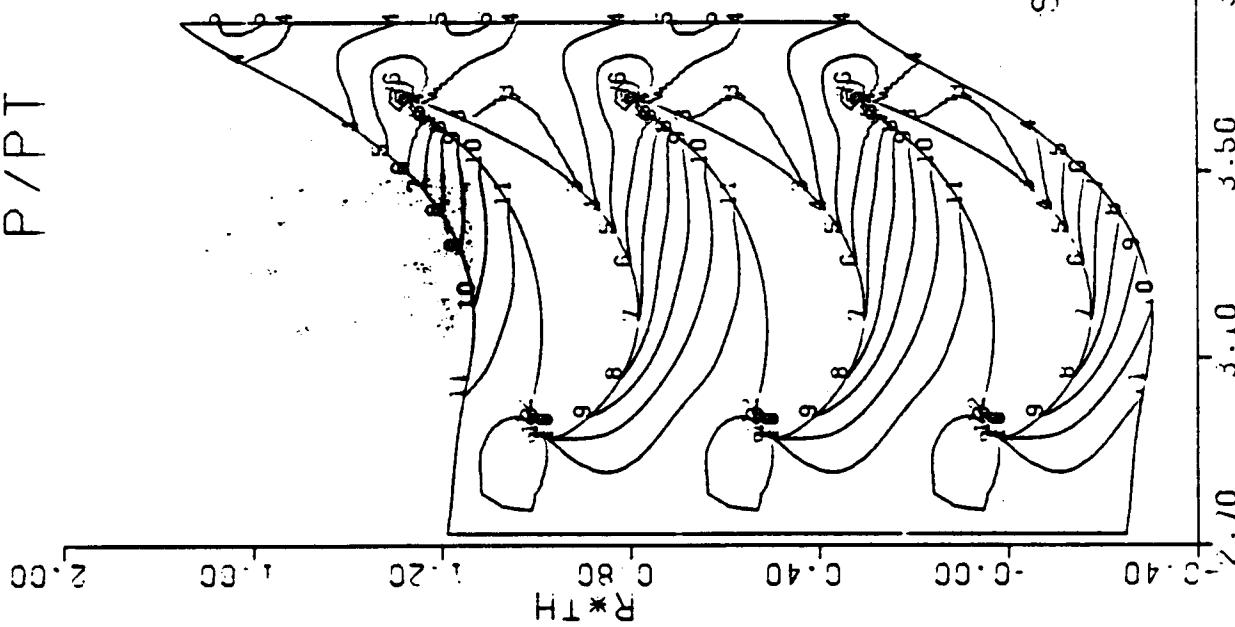
08/20/87  
DL<sub>S</sub>

P / PT

CONTOURS

EL ALND	C.00/6000
6.34	C.00/5000
6.78	C.00/4000
7.9	C.00/3000
10.0	C.00/2000
11.4	C.00/1500
12.4	C.00/1000
13.4	C.00/600
14.4	C.00/300
14.7	C.00/100
15.0	C.00/50
15.4	C.00/20
15.7	C.00/10
16.0	C.00/5
16.4	C.00/2
16.7	C.00/1
17.0	C.00/05

SSME ATD HPFTP 2V 1.D. 3D ISGRARS

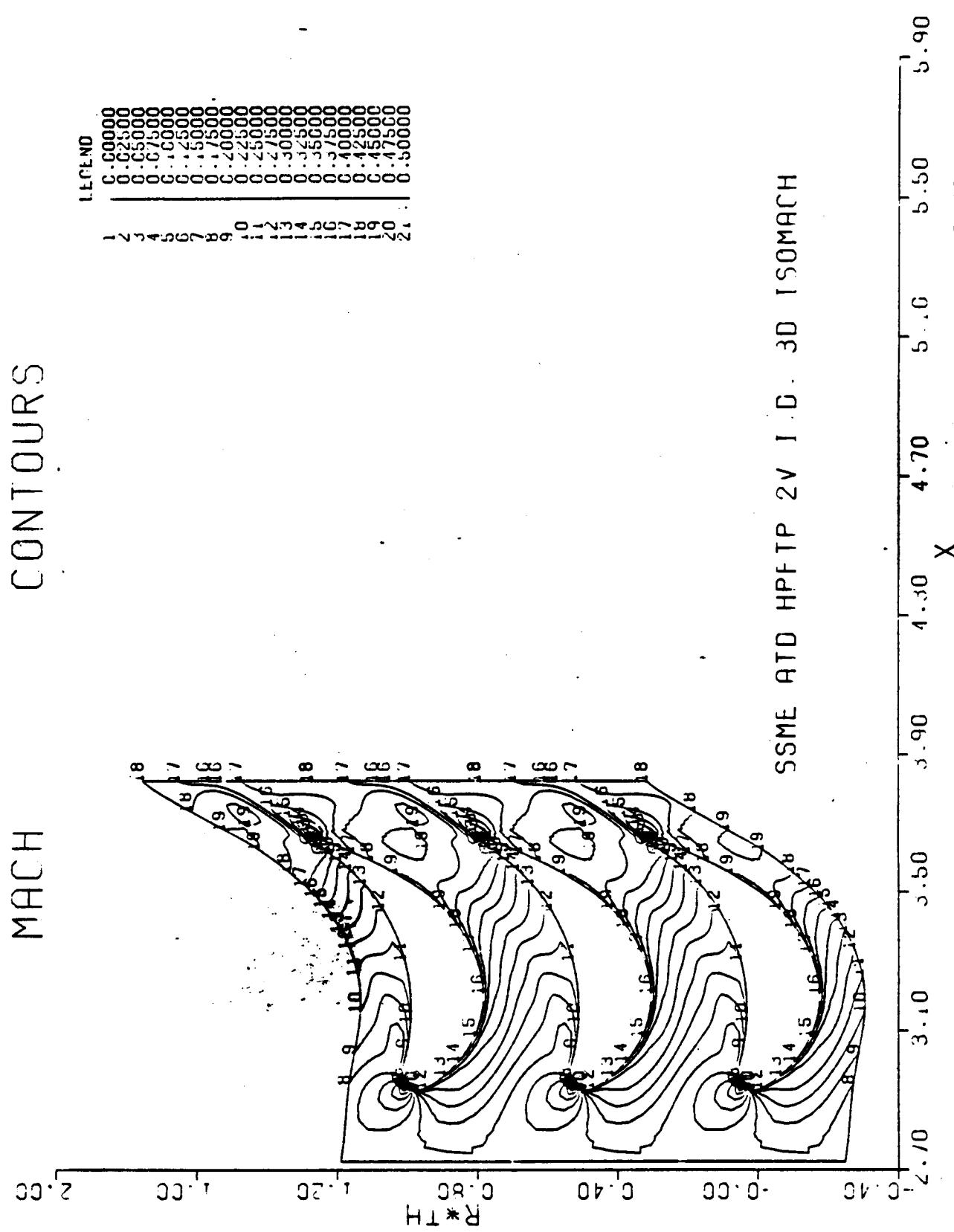


SI INLE: NI 3D GRID C-GRID INLET STRUT. R. RCWT. Q.

02/08/88, b30, 48

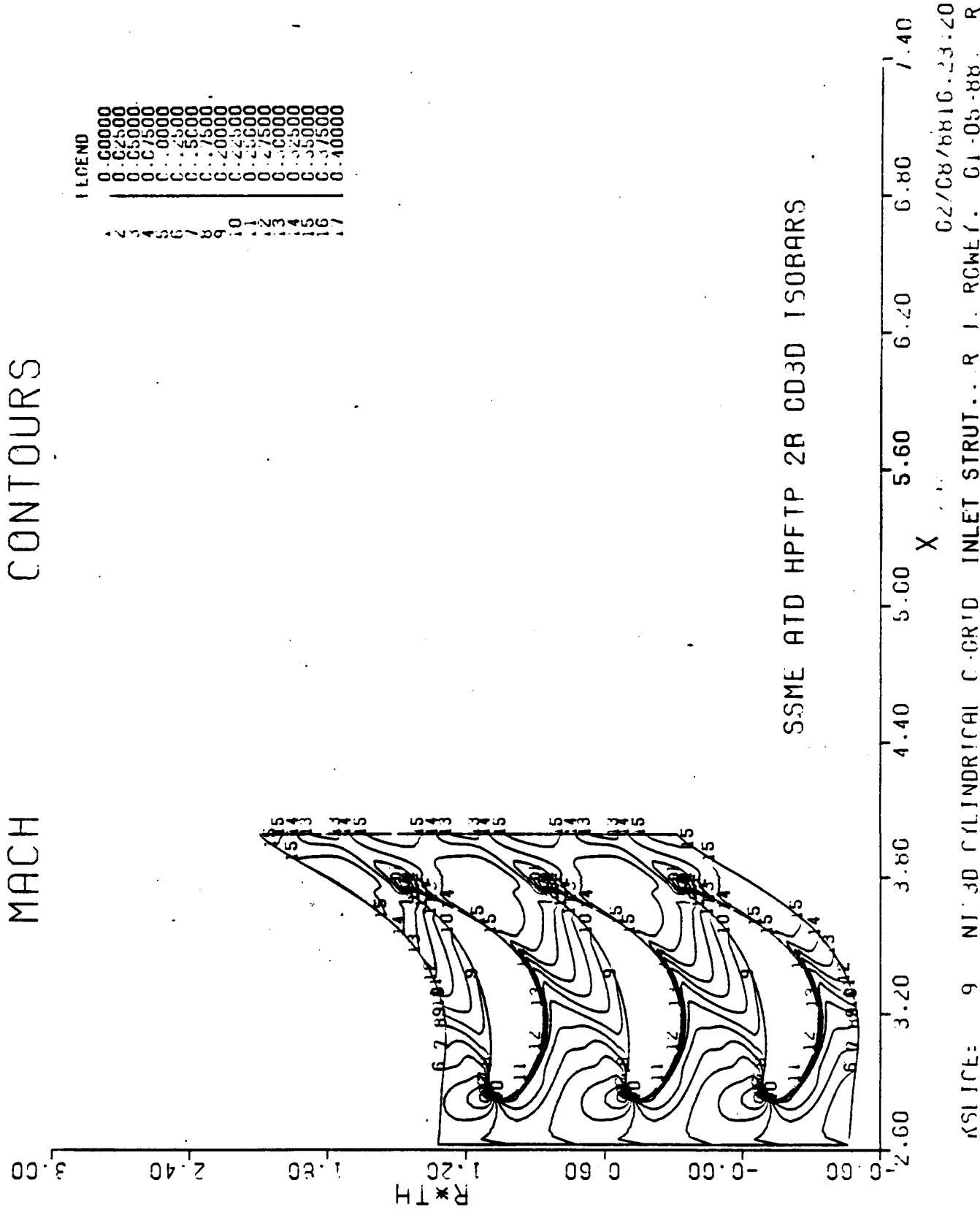
# MACH

# CONTOURS



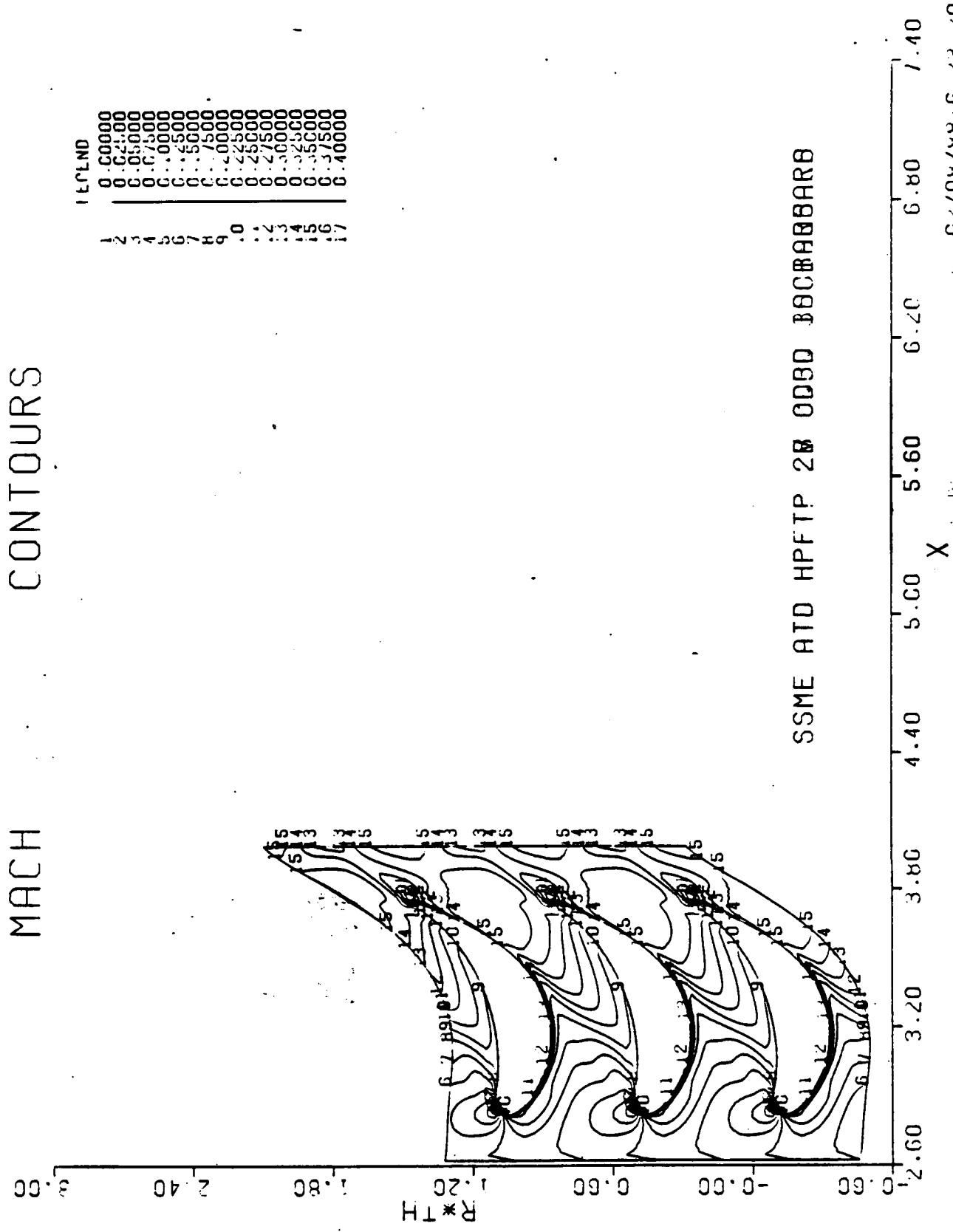
# MACH

# CONTOURS



# MACH

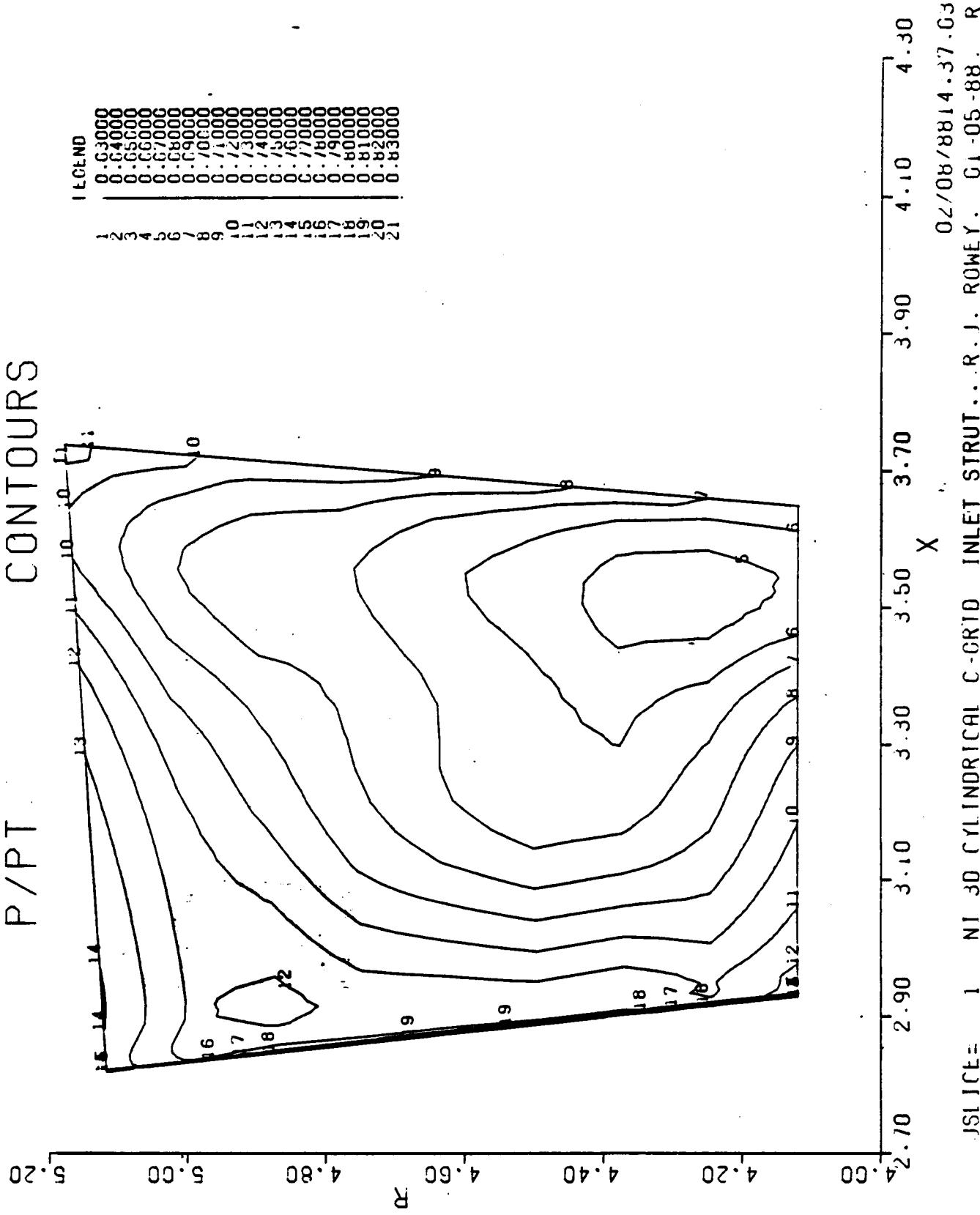
# CONTOURS



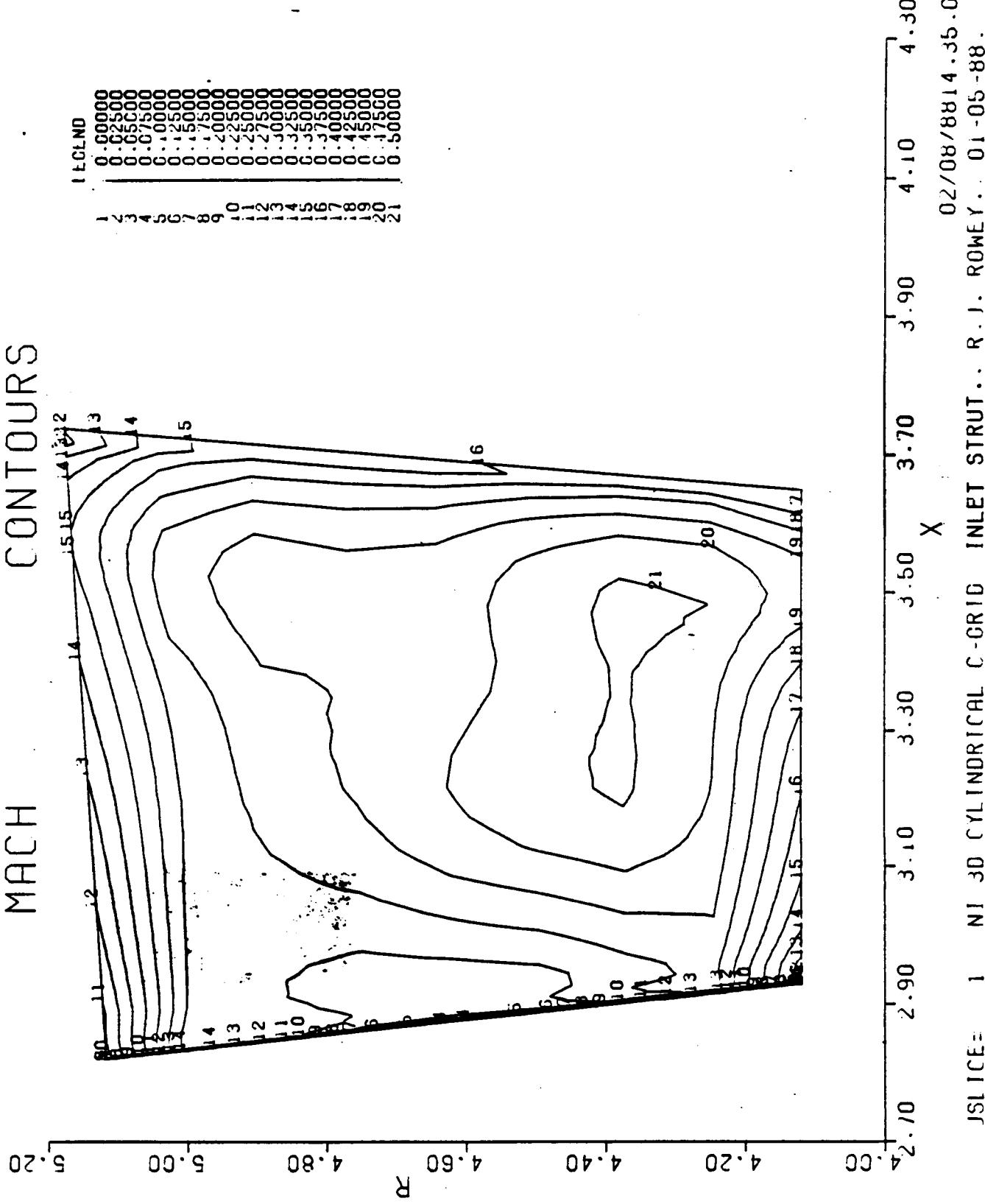
KSI FILE: 9 NI 36 CRY INDRICAI C-GRID INLET STRUT.. R J. RGWE R G1 -05 -8K R

# P / PT

## CONTOURS



# MACH CONTOURS



JSLICE= 1 NI 3D CYLINDRICAL C-GRID INLET STRUT.. R. J. ROWEY.. 01-05-88. R  
02/08/88 14:35:01

SSME F1 FINAL ZV. R.J. ROWEY 6-9-87

STRESS VS. SPAN

WAE = 159.0

RPM = 8.

PULL = 0.

DENG = 0.33300

1 SIC P/R SHROUD

2 SIC P/R CIL+SHROUD

3 SIC P/R SIC SHROUD

4 SIC P/R + SIC SHROUD + SIC NB.

5 SIC P/R + SIC SHROUD + SIC NB.

CONDITION:

100% PCT. TADP. R.J.  
ROWEY. 6-10-87.

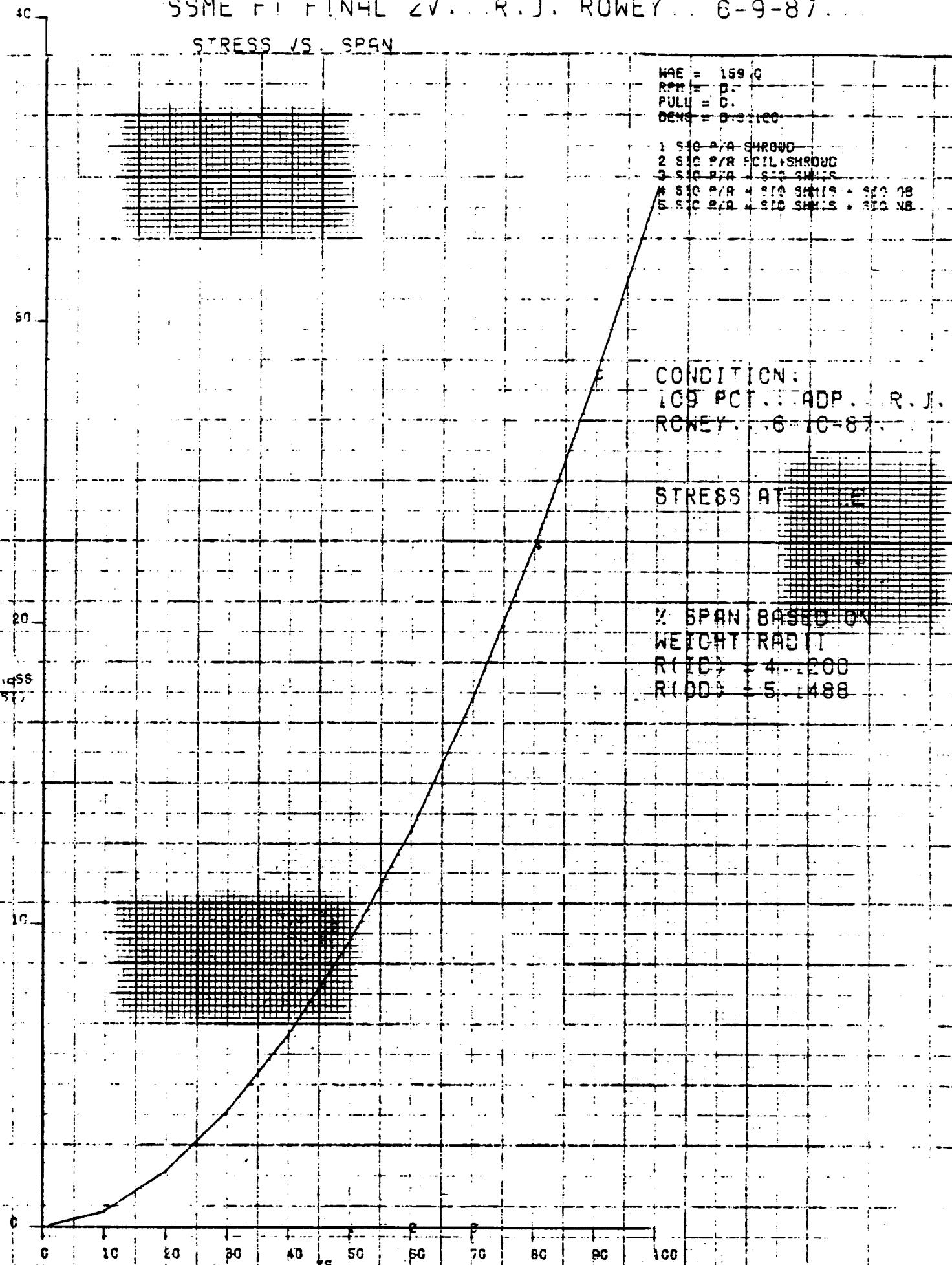
STRESS AT

% SPAN BASED ON

WEIGHT RAD (1)

R1C1 = 4.1200

R1D1 = 5.1488



## U456 - FINITE TRANSITION INTEGRAL BOUNDARY LAYER DECK

DATE 07/26/87

TIME 11:34:24

SECOND VENETIAN BLIND NUMBER: 06/11/87. PJ

REFUEL 2 GROSS RATE = RTF = 4.12

4.00% TU

INLET

EXIT

MACH NO. 0.288

0.482

GAS ANGLES 141.06

152.40

PRESSURE SIDE

REF. REYNOLDS NO. \*\*\*\*\*

0.0100

0.0090

0.0080

0.0070

0.0060

0.0050

0.0040

FRICTION COEF.

0.0030

0.0020

0.0010

0.0000

0.0 0.5 1.0 1.5 2.0

S DISTANCE (INCHES)

TRANSITION CHART

0.0 0.5 1.0 1.5 2.0

S DISTANCE (INCHES)

## U456 - FINITE TRANSITION INTEGRAL BOUNDARY LAYER DECK

DATE 07/20/87

TIME 11:37:45

SECOND VENUE 07/20/87. 06/11/87. PJ

RFUEL 2 1750 PINTS 4.37 RTE = 4.38

4.002 TU

INLET EXIT  
MACH NO. 0.1273 0.459  
GAS ANGLES 142.41 158.97

REF. REYNOLDS NO. 9872195

PRESSURE SIDE

0.0100  
 0.0080  
 0.0060  
 0.0040  
 0.0020  
 0.0000  
 0.0050  
 0.0030  
 0.0010

0.0000

0.0000

0.0000

0.0000

0.0000

0.0000

0.0000

0.0000

0.0 0.5 1.0 1.5 2.0

S DISTANCE (INCHES)

TRANSITION CHART

0.0 0.5 1.0 1.5 2.0  
S DISTANCE (INCHES)

## U456 - FINITE TRANSITION INTEGRAL BOUNDARY LAYER DECK

DATE 07/29/87

TIME 11:41:06

SECOND VENUE: R. J. REYNOLDS 06/11/87. RJ

REFUEL 2 HEADS: 3.62 RIF = 4.65

4.002 10

INLET

EXIT

MACH NO. 0.262

0.436

GAS ANGLES 138.06

158.66

PRESSURE SIDE

REF. REYNOLDS NO.

\*\*\*\*\*

0.0100

0.0090

0.0080

0.0070

0.0060

0.0050

0.0040

0.0030

0.0020

0.0010

0.0000

FRONT SURFACE

0.5

1.0

1.5

2.0

S DISTANCE (INCHES)

## TRANSITION CHART

0.0

0.5

1.0

1.5

2.0

S DISTANCE (INCHES)

## U456 -- FINITE TRANSITION INTEGRAL BOUNDARY LAYER DECK

DATE 07/29/87 TIME 15116

SECOND VENUE 06/11/87 RJ

REFUEL 2 07/29/87 RTF 4.91

4.002 19

INLET EXIT

MACH NO. 0.240 0.403

GNS ANGLES 135.99 154.67

PRESSURE SIDE

REF. REYNOLDS NO. \*\*\*\*\*

0.0100

0.0080

0.0060

0.0040

0.0020

0.0010

0.0008

0.0006

0.0004

0.0002

0.0001

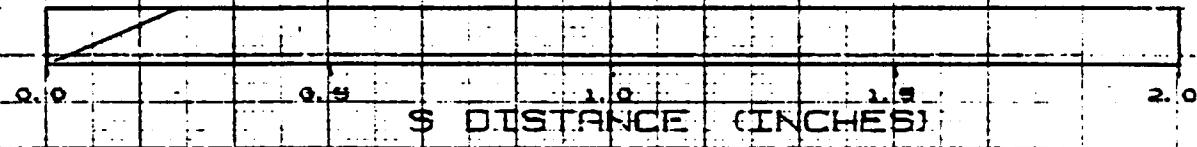
0.0000

DOWN

0.0 0.5 1.0 1.5 2.0

S DISTANCE (INCHES)

TRANSITION CHART



## U456 - FINITE TRANSITION INTEGRAL BOUNDARY LAYER DECK

DATE 6/28/87

TIME 11:54:23

SECOND VENUE CFD REYNOLDS 06/11/87...RJ

RFUEL2 LEGS0 BLUFF 12' PIE= 5.18

4.002 TBL

INLET

EXIT

MACH NO. 0.204

0.367

GAS ANGLES 130.14

151.82

PRESSURE SIDE

REF. REYNOLDS NO.

\*\*\*\*\*

0.0100

0.0090

0.0080

0.0070

0.0060

0.0050

0.0040

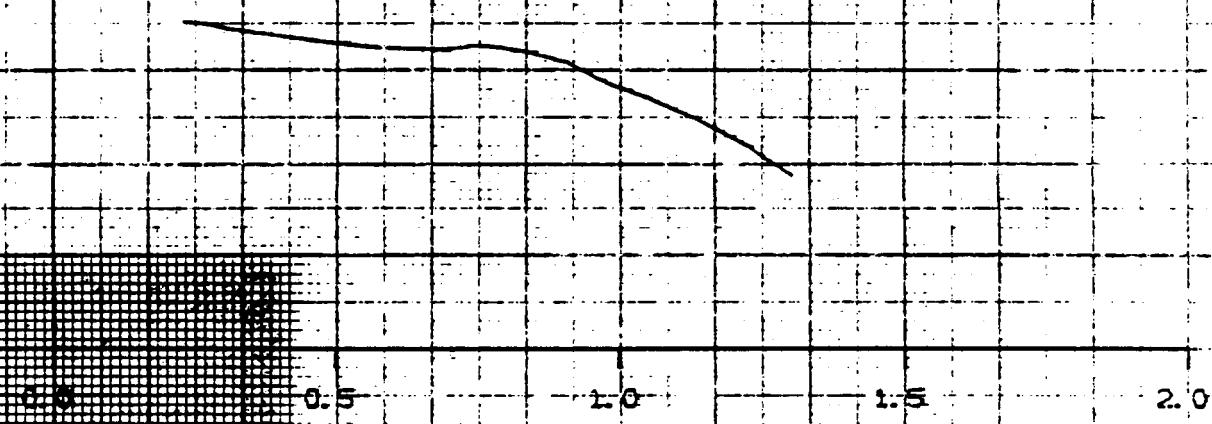
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0.0020

0.0010

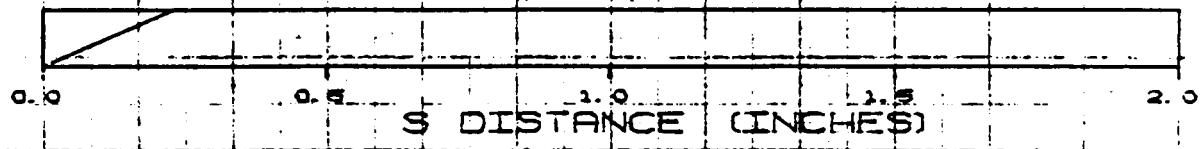
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WALL UBLW



S DISTANCE (INCHES)

TRANSITION CHART



S DISTANCE (INCHES)

2.0